EVALUATION OF ISO 11785 LOW-FREQUENCY RADIO IDENTIFICATION DEVICES AND THE CHARACTERIZATION OF ELECTROMAGNETIC INTERFERENCE IN PRACTICAL CATTLE MANAGEMENT SCENARIOS

by

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Abstract

Low-frequency (LF) radio frequency identification (RFID) transponders (n = 1,993) representing both full-duplex and half duplex air interface technologies were evaluated. Transponders representing five manufacturers and seven types were evaluated for read distance (RD), resonance frequency (RF) and voltage response (VR). LF RFID transceivers (n = 24) were also evaluated for performance and variance as tested by read distance.

Transponders were sorted into four categories based on RD performance on three transceivers, “Top 25%,” “Middle 50%,” “Bottom 25%,” and “No Read.” These categories were used for evaluation of transponders and transceivers in experiments one and two, respectively.

In experiment one, the mean RF of the “Top 25%” transponders were closer to 134.2 kHz ($P < 0.05$) within a transponder type (TT). TT and mean RD performance category interacted to affect the VR of transponders ($P < 0.05$); transponders with lower VR tended to have longer RD within a TT.

In experiment two, sixty transponders from the “Middle 50%” were used to evaluate transceivers. Transceivers represented five manufacturers and five transceivers per manufacturer; one transceiver was eliminated from testing due to mechanical problems. There was a significant interaction ($P < 0.0001$) for TT and transceiver manufacturer. This indicated that transceiver performance was greatly dependant on TT being interrogated. TT and transceiver manufacturer interacted to affect RD variance ($P < 0.05$) demonstrating that transceiver RD will vary depending on TT being interrogated.

In the final study, electromagnetic interference (EMI) was evaluated in fourteen livestock auction markets, four feedlots and five cattle abattoirs. The presence of EMI is known to impair the performance of RFID equipment. However, this phenomenon in livestock management settings has not been quantified in the scientific literature. EMI (134.2 $\pm$ 25 kHz) was observed in all abattoirs. However, the extent and duration of EMI varied depending on individual abattoir. The processing, load and unload areas were evaluated in commercial feedlots. The most EMI was observed in the processing area. Finally, EMI was observed at the sale ring exit at two livestock auction markets. EMI exists in livestock management settings and may negatively impact the performance of LF RFID.

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CHAPTER 1 - A Review of the Literature

Introduction

Recently, radio frequency identification (RFID) has been increasingly implemented into many aspects of our daily life. RFID has been in existence since the 1940's and was widely used during WWII by the British to distinguish between friendly vs. enemy aircraft (Domdouzis et al., 2007). Since that time, the application of RFID has increased greatly. The general public has become more aware of this technology recently as more publications are available on the subject matter. Currently, RFID is used in electronic article surveillance systems, employee recognition for access to controlled areas, monitoring of supply in warehouses, automobile manufacturing, traffic quick pass systems, and companion animal programs such as "Home Again" commercial program just to name a few of its applications. For obvious reasons livestock identification one market where this technology has received significant attention.

Animal identification in the livestock sector is gaining popularity as producers are looking for strategies to: 1) increase consumer confidence through improved food safety and traceability, 2) improve management tools, 3) increase international trade and, finally, 4) appease concerns regarding animal health, and bio-terrorism (Tonsor and Schroeder, 2006). Electronic identification (eID) of livestock has been investigated recently (Wallace et al., 2007; Basarab et al., 2006; A. Bryant unpublished data, 2007) as it is gaining prominence as a means of individual identification, allowing producers to better manage their livestock and meet requirements for export market verification programs. Moreover, the National Animal Identification System (NAIS) and Country-of-Origin Labeling (COOL) are increasing livestock producer awareness of animal identification. Beef producers are neither strongly supportive of nor strongly against

NAIS, but see the primary benefits of the program in disease monitoring and recapture of lost foreign markets as a consequence of the discovery of bovine spongiform encephalopathy (BSE) in December, 2003 (Breiner et al., 2007).

The use of low-frequency RFID has been suggested by the United States Animal Identification Plan (USAIP) bovine standards subcommittee (2004) as the best means of individual identification currently available to beef producers. A great deal of research has been conducted on low-frequency ISO 11785 RFID primarily in small ruminants and monogastric livestock by researchers in Europe. The previous research has focused on low-frequency RFID in rumen boluses (Caja et al., 1999; Ghirardi et al., 2004, 2006) and injectable (Caja et al., 1999, 2005; Conill et al., 2000; Babot et al., 2006) transponders. Research has not explored in great detail the use of RFID in ear tags for livestock. However, this form of RFID is becoming the de-facto form factor, especially in US dairy and beef cattle.

The objective of this literature review is to explore research that has evaluated low-frequency RFID ear tags (transponders) in terms of read distance, resonance frequency, and voltage response. Additionally, electromagnetic interference which can negatively impact the performance of RFID systems will be explored.

National Animal Identification System

The United States National Animal Identification System (NAIS) has become an increasingly contentious issue over the past five years as both proponents and opposition have published a great deal of literature on the subject. In December 2003 the first cow with BSE was discovered in Washington State; this event leading to a cascade of several countries refusing to accept US beef. Subsequently, the US government decided to increase pressure on the implementation of a NAIS. In an effort to implement the system while addressing the concerns of some participants the program has undergone a number of changes. However, the core steps which will make the program effective have not changed.

There are three primary steps to the successful implementation of the NAIS. First, livestock producers need to register their premises, second, individual animals need to be identified and third, the ability to track individual or groups of animals from one premises to another throughout the lifetime of the livestock (USDA, 2006). As of April 2, 2008, 31.8% of premises have been registered through the NAIS (USDA, 2008a). Due to an under estimation of premises within an state, two states, Massachusetts and Wisconsin, have over 100% of the estimated number of premises registered (USDA, 2008a). In contrast, a number of other states have less than 10% of the estimated number of premises registered (USDA, 2008a). There is a great deal of variability in the acceptability and implementation of NAIS programs throughout the United States.

To accomplish the second step, USDA published "Program Standards and Technical Reference," a document which provides specific requirements regarding numerous animal identification options (USDA, 2008b). A thorough outline of minimum requirements for electronic identification devices to qualify for use with NAIS explains that all transponders must be ISO 11784 and 11785 compliant as certified by the International Committee for Animal Recording (ICAR) conformance, must have a 100% readability at 60 cm from a transceiver, must last for the lifetime of the animal while being machine readable the entire time, and finally, transponders must be tamper evident (USDA, 2008b). Participants in NAIS have registered their premises and are beginning to take a more active role in individual animal identification.

The final step addresses tracking or traceability of individual animals. In the previously mentioned program standards document the codes which are entered into a database to record movement of animals is also provided (USDA, 2008b). The USDA provides a list of approved "animal tracking databases" for use in tracking individual animal and group/lot movements available to producers and interested parties; options for both privately held and State databases are available (USDA, 2007b).

In an effort to further increase participation in and understanding of the NAIS and animal disease traceability efforts, USDA has released an updated business plan which identifies seven strategies they intend to emphasize: 1) prioritize NAIS implementation by species/sectors, 2) harmonize animal identification systems, 3) standardize data elements of disease programs to ensure compatibility, 4) integrate automated data capture technologies with disease programs, 5) partner with states, tribes and territories, 6) collaborate with industry, and 7) advance identification technologies (USDA, 2007a). In a variety of ways this business plan is being implemented and producers can easily participate. Just recently, USDA provided in a news release to producers, the intent to allow participation in NAIS to coincide with existing voluntary marketing programs and eventual cooperation in country-of-origin labeling (USDA, 2008c).

The idea of animal ID for disease monitoring is not new. Augsburg (1990) discussed the need for animal ID for traceback of swine with drug residues to provide for increased food safety. Dzuik (2003) noted that animal identification has been around for a long time in the form of hot iron brands and ear marks but that recently the livestock sector has begun to use other forms of identification, including eID. Increased use of individual animal ID will allow for increased levels of accountability, thereby decreasing the potential for fraud, improved traceability, increased monitoring of animal health, and improvements in meat inspection, quality and brand loyalty by consumers (Dzuik, 2003). At this point in time, the USDA has approved the use of low-frequency RFID for individual animal ID to comply with NAIS.

Radio Frequency Identification Scope and Applications

There are three main components of an RFID system: an interrogator and a data accumulator which interprets the internal code of the transponder post interrogation, the combination of these two components is quite common and known as a transceiver; the final component is a transponder which houses internal information which must be transmitted to the data accumulator after interrogation (McAllister et al., 2000). In animal ID, the transponder's internal information is the 15-digit animal identification number (AIN) used to provide a unique individual ID number. A RFID system is similar to barcodes except that it communicates via radio waves and does not require line of sight for interrogation, the data can be communicated from the transponder to the transceiver through materials.

There are number of frequencies to which RFID can be applied. Low-frequency ranges from 100-500 kHz and is most commonly used in access and inventory control and animal identification, this system provides short to moderate read distances (AIMI, 1998). Low-frequency RFID can be interrogated through wood, body tissue and plastic (Wallace et al., 2006), but not metal (McAllister et al., 2000), which makes it applicable to the livestock industry. Intermediate-frequency ranges from 10-15 MHz with short to moderate read distances and are used primarily for access control and smart cards (AIMI, 1998). High-frequency is used in toll road and railroad car monitoring applications through communicattion at 850-950 MHz and 2.4-5.8 GHz; this frequency has long read distances and can be quite expensive (AIMI, 1998).

Current uses of RFID in everyday activities include: recent application in Wal-Mart where RFID is being used for tracking of product from production through warehouses to individual stores. Another application of low-frequency RFID is electronic article surveillance systems in retail stores to prevent shoplifting. Traffic toll booths such as K-TAG and most quick pass systems also use high frequency RFID. Libraries and pharmaceutical manufacturers are using this technology to monitor inventory and location of products.

Low-frequency RFID is the primary focus of this literature review and will receive the remainder of attention. This technology, as it applies to livestock, must conform to International Organization for Standardization (ISO) 11784 and 11785 to be accepted. ICAR is the entity tasked with the responsibility of testing transponders and transceivers for conformance to ISO standards. In the future, they will have performance standards to which the technology must conform to as well. There is a new proposed ISO standard, 24631 with four parts which specify the testing methods for transponders and transceivers with and without a manufacturer code regarding conformance and performance (ISO, 2007). It is not yet an official standard but intends to provide testing centers with specific instructions for conducting performance tests.

ISO 11784 identifies the code structure of transponders used for animal identification (ISO, 1996a). A transponder is composed of a chip, integrated circuit and capacitor (HDX only). ISO 11785 specifies the technical concept for low-frequency transponders and transceivers used in animal identification. There are two low-frequency air interface technologies defined in ISO 11785, the full-duplex (FDX-B) and half duplex (HDX) systems. ISO 11785 requires both FDX-B and HDX transponders to communicate with transceivers at 134.2 $\pm$ 3 kHz (ICAR, 2007). FDX-B transponders transmit their internal code during the activation period of the transceiver (ISO, 1996b). FDX-B transponders require 50 ms (milliseconds) to be activated and transmit their internal code; if activation occurs but a code is not received the activation continues to 100 ms (ISO 1996b). HDX transponders are charged to send their internal code during an interruption in the activation signal of the transceiver (ISO, 1996b). If a transceiver does not receive an internal code or is not activated by and FDX-B transponder the transceiver will pause sending an activation signal (ISO, 1996b). If an HDX signal is received activation will continue to pause for an additional 20 ms, during this time the HDX transponder must transmit its internal code (ISO, 1996b). If no HDX signal is received activation will reinitiate (ISO, 1996b).

ISO 11785 also specifies that compliant transceivers must activate both FDX-B and HDX transponders at 134.2 kHz (ISO, 1996b). The technical characteristics of a transceiver which both interrogates and interprets the internal code of a transponder are further specified (ISO, 1996b). In the proposed standard 24631, Parts 2: conformance and 4: performance, testing procedures for transceivers are explicitly stated to provide increased uniformity in testing (ISO, 2007). ISO and ICAR standards do not specify form factor of the transponder and therefore apply to injectable and bolus transponders and ear tags.

ISO 11784 and 11785 Ear Transponders and Transceivers

The focus of our research has been in ear tag transponders as they are the most widely accepted form of identification in the US and provide an immediate visual assurance if the animal is or is not identified. The primary variables of interest when evaluating literature on electronic ear transponders are read distance, resonance frequency and voltage response.

Read distance

Read distance defined is the distance away from the transceiver that a transponder is first successfully interrogated. Low-frequency RFID technology has been evaluated for application in swine (Blair et al., 1994; Babot et al., 2006; Santamarina et al., 2007), cattle (Blasi et al., 2003; Ghirardi et al., 2004; Basarab et al., 2006) and sheep (Edwards et al., 2001) as a means of effective ID. While the use of eID technologies by livestock managers is increasing, the performance and reliability of RFID equipment has been identified as a concern (Breiner et al., 2007). Low-frequency RFID which complies with ISO 11784 and ISO 11785 has been accepted by the United States Animal Identification Plan (USAIP) bovine standards subcommittee as the best means of individual animal identification currently available (USAIP, 2004).

In an evaluation of eID in 4-H livestock projects, Rusk (2002) reported that while read distance of ear tag transponders was not a problem there are retention and readability issues which need to be addressed. Of 508 pigs with eID 67% of transponders were readable and of 625 sheep with eID 96% were readable transponders. The low percentage of readable transponders in the pigs was attributed to either loss or damage primarily from other pigs chewing on the transponder. A great deal of research regarding readability and retention of eID tags in production settings has occurred (Eradus and Jansen, 1999; Babot et al., 2006; A. Bryant unpublished data, 2007) however there is limited published data on laboratory trials. To evaluate the effect of decreasing temperature on read distance and readability of transponders and transceivers Wallace et al. (2006) measured read distance of transponders held in the best orientation to handheld transceivers. Six types of transponders were tested on five brands of handheld transceivers at three varying temperatures (22˚C, 2˚C, and -19˚C). They observed two-way interactions ($P < 0.05$) between transponder x transceiver, transponder x temperature, and transceiver x temperature, in addition to a three-way interaction ($P < 0.05$) of transponder x transceiver x temperature. While all transponders and transceivers had successful interrogations at all temperatures a noticeable decrease in read distance occurred with decreasing temperature. This agrees with Ribó et al. (2001) who concluded RFID transponders can be interrogated and telegraph and transceivers can interrogate regardless of temperature; however, the read distance will be impacted.

Resonance Frequency and Voltage Response

While a number of manufacturers of ISO 11784 and ISO 11785 compliant transponders exist not all transponder types have the same or similar levels of performance (Wallace, 2007; Bryant, 2006). Based upon previous studies in our laboratory, a number of factors contribute to successful interrogation of transponders (A. Bryant unpublished data, 2007). ICAR (2007) requires ISO 11785 transponders to communicate at a resonance frequency of 134.2 $\pm$ 3 kHz for compliance.

Voltage response (VR) is the amount of power, in volts (V), required by the transponder to transmit its 15 digit AIN to a transceiver, or the magnitude of wave oscillation when a transponder is modulating. Resonance frequency (RF) is the radio frequency, measured in hZ, at which a transponder responds or modulates when transmitting its information. A. Bryant (unpublished data, 2007) showed that RF and VR are affected by transponder type ($P < 0.0001$). A. Bryant (unpublished data, 2007) found that the two transponder types with RF outside the ICAR standard range were the two transponder types with the shortest read distance. Within a type of transponder each individual transponder may not meet ICAR (2007) requirements. However, if a large enough portion of transponders are within compliance then the mean of that type will high enough for overall compliance (A. Bryant unpublished data, 2007) suggesting that there might be a lack of consistency for some types of transponders. Poor performance on read distance is correlated to lack of resonance frequency conformance (ICAR, 2005; A. Bryant unpublished data, 2007).

Transceivers

While transceivers conform to ISO standards potential problems may arise with overall consistency. Published literature does not provide research regarding read distance variation across transceiver manufacturers. The transceiver with the greatest read distance may not have the least variance among all transceivers within a manufacturer. A question of quality control is posed at this point: Is the company providing a high quality (read distance) consistent (minimized variation) product?

The USAIP bovine standards subcommittee (2004) for the NAIS recommended a minimum performance level of 100% interrogation by transceivers with transponders a minimum of 60 cm away at best orientation. There is a limited amount of published research (Basarab et al., 2006; Wallace et al. 2006 and 2007) that evaluates at transponder performance across multiple transceivers in a controlled laboratory environment. Basarab et al. (2006) compared two transceiver system designs and found that while both systems could interrogate transponders the Allflex Two Lane Multi-Panel system provided higher readability of transponders than the Digital Angle One Lane RFID system. Wallace et al. (2006) found that read distances of transceivers decreased with decreasing temperature but that interrogation of transponders was still possible. In a study using three different multi-panel transceiver systems the design of the system and transceiver brand influenced readability of transponders (Wallace et al., 2007). Additionally, Bryant et al. (2006) showed that the materials and design of transceivers can impact the read distance and variability. Differences in transceiver performance exist; however, the extent to which transceivers vary within and among brands still needs further research.

Electromagnetic Interference

Radio frequency waves are also electromagnetic waves whose frequencies lie between 30 Hz and 300 GHz (Lahiri, 2006). The low-frequency being used for animal identification occurs at 134.2 kHz, which lies in the middle of the electromagnetic frequency.

Therefore, when evaluating interference with RFID it is applicable to evaluate electromagnetic waves, electromagnetic interference (EMI).

EMI occurs when electromagnetic waves from one electronic device obstruct the normal functions of another electronic device (de Sousa et al., 2002). The increased use of and advancements in RFID have lent this technology to be potentially impacted by EMI. EMI has a negative impact on the ability of a RFID system to work effectively and poses a significant challenge to successful implementation of these systems.

Porter et al. (2006) noted that the best performance of an RFID system is determined by the available transmitting power of the transceiver, the power available within the transponder to respond to the signal of the transceiver and environmental conditions, including EMI. Companies manufacturing transponders and transceivers for livestock identification have noted that EMI can be a problem when installing and implementing a system. The recent use of Growsafe® Systems Ltd. (Airdrie, AB, Canada) in research on feeding patterns has led to discussion of EMI in some published studies (Schwartzkopf-Genswein et al., 1999; DeVries et al., 2003), however exact quantification still remains unanswered.

EMI has been identified in other environments and its impact documented in published literature. For example, EMI can have significant effects on patients with implanted pacemakers and implanted cardioverter-defibrillators (de Sousa et al., 2002). Electronic surveillance systems used in many retail establishments were evaluated to determine the impact of the EMI on patients with pacemakers; de Sousa et al. (2002) found that unless patients stood in the electromagnetic field of the electronic surveillance system for prolonged periods EMI would not negatively impact the function of the devices. EMI can impede the communication function of high performance integrated circuits, even at very low levels of EMI (Wang et al., 2006).

Integrated circuits allowed for RFID transponders to be reduced in size from the original form factors and are now an integral part of low-frequency RFID. If integrated circuits at high frequencies can be impacted by EMI it is likely that it will do the same at lower frequencies. There are a number of examples of EMI documentation at frequencies other than the low-frequency observed in our research.

Cellular phones emit electromagnetic waves which can cause interference with some medical devices. Monitoring systems, ECG telemetry monitoring systems, infusion pumps and ventilators have all been identified as impacted by EMI from cellular phones (Guidance, 1996). Hayes et al. (1997) evaluated the impact of interference from cellular telephones when used by patients with cardiac pacemakers and found that if the telephones were used in the normal position at the ear there was not a negative influence however, if the telephone was held over the pacemaker a clinically significant event occurred in 1.7 percent of the tests. EMI has been observed in a number of settings and has been noted as a problem in livestock production settings by industry and researchers, however the direct amount of EMI has not been quantified.

Summary

The cattle industry is moving rapidly towards a more intensively managed system in which all producers must compete for profit with those who are implementing advanced technology systems. The current promotion of a National Animal Identification System, Country-of-Origin Labeling, and access to foreign markets is providing further incentive to producers to implement individual animal identification systems.

Radio frequency identification, currently using the low-frequency 134.2 kHz, is a popular method to accomplish individual animal identification. While a number of manufactures of low-frequency RFID transponders and transceivers exist, not all products have the same performance quality. Read distance of transponders and transceivers are not consistent (Bryant et al., 2006; Wallace et al., 2007). All low-frequency RFID transponders and transceivers must meet ISO 11784 and 11785 (1996a, 1996b) and ICAR (2007) requirements in order to be accepted by the USDA and the livestock industry. However, Bryant et al. (2006) and Wallace et al. (2006) showed that a great deal of variability among transponder and transceiver manufacturers exists. An inconsistent product does not encourage implementation of this technology. The resonance frequency and voltage response of transponders has an impact on the achieved read distance ($P < 0.001$) as noted by A. Bryant (unpublished data, 2007). Other factors also contribute to poor performance of products, including electromagnetic interference.

EMI has been documented in a number of settings other than animal agriculture (Hayes et al., 1997; de Sousa et al., 2002; Wang et al., 2006). With the increased use of Growsafe® Systems Ltd., an RFID individual animal feeding management system, in research EMI has been suggested as a problem impacting this technology (Schwartzkopf-Genswein et al., 1999; De Vries et al., 2003). Manufacturers of transponders and transceivers have identified EMI as a problem as they implement and develop systems for livestock producers, however this information is anecdotal and not documented in peer reviewed journals.

As individual animal identification continues to increase it is important to understand and address these issues. Ongoing research evaluating the performance of ear tag transponders is important for the US livestock industry. The performance of this technology must be scrutinized in order to assure it conforms to ISO 11784 and 11785 as well as to future ICAR performance standards. Nonconformance leads to poor performance of equipment and unsatisfied producers thereby reducing the overall acceptability of this advanced identification technology.

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CHAPTER 2 - Selection of transponders and methodology of laboratory work

The following studies were completed as a portion of a grant funded by USDA-APHIS entitled "Impact of Environmental Interferences and Performance Variation on RFID Transponder and Transceiver Reliability and Economic Assessment of RFID Technology Implementation in Animal Production Environments." This introduction is intended to provide background regarding the selection methodology and subsequent testing of transponders. It will also address some of the problems and challenges faced throughout the laboratory portion of the reported work.

The objective of the research conducted was to evaluate low-frequency Radio Frequency Identification (RFID) transponders, ISO 11784 and 11785 (ISO, 1996a, 1996b) that were acquired through normal channels of distribution and readily available for purchase by any commercial customer. The transponder manufacturers were not contacted directly to avoid potential bias through extensive pre-testing. Transponders were evaluated in a laboratory and then in real-world cattle management settings. In May 2006 five manufacturers of transponders were identified as those commercial entities providing the majority of transponders into the low-frequency RFID market, with one manufacturer providing two different types of transponders. Five hundred transponders for each type were acquired, providing a total pool of 3,000 transponders for further testing (Figure 2.1, Table 2.1).

Within each type (manufacturer, chip type used by manufacturer, air interface), transponders were assigned a consecutive experimental number which was recorded with a black permanent marker on the surface of the transponder. This number was entered into a spreadsheet along with the corresponding 15-digit animal identification number (AIN). The visual number provided a simple method for identifying each tag throughout the laboratory testing process.

A read distance test was initially performed on all 3,000 transponders. Read distance defined is the distance (cm) away from a transceiver when a transponder is first successfully interrogated. The transponders were tested against three low-frequency RFID transceivers (Table 2.1). At the beginning of this test procedure, the Edit ID transceiver (SN OG159001) failed to interrogate a number of transponders resulting in a "no read" for read distance. Consequently, three transceivers each from three different manufacturers were used to evaluate transponder read distance performance. Through communication with transponder and transceiver manufacturers it was determined that there was an incompatibility between one transponder chip and the operating software version on the Edit ID transceiver. Therefore, to provide each transponder an adequate opportunity to be interrogated, two additional transceivers were added to the test (Allflex (SN 204404902) and Destron (SN 063001)). Moreover, read distances were collected in duplicate from each transponder evaluated (n = 18,000).

Upon completion of read distance test, the data was analyzed using PROC GLM in SAS (SAS Inst. Inc., Cary, NC) including the main effects of transponder type, transceiver manufacture and their interaction. Read distance was also used to determine "average read distance rank" for transponders. The mean of duplicate tests for each transponder was calculated based on performance observed from each transceiver. The mean read distance for each transponder on each transceiver was then assigned a number 1 to 500 within a type from least to greatest. The numbers assigned to each transponder within a type were then averaged to calculate the "average read distance rank." Average read distance rank was then used to sort the transponders into four read distance performance categories: Top 25%, Middle 50%, Bottom 25% and No Read. Any transponder that realized at least one unsuccessful interrogation out of six opportunities was included in the “No Read” category.

A subset of transponders from each of the aforementioned categories was selected and evaluated for resonance frequency and voltage response. The subset of transponders consisted of: Top 25% (n = 50 transponders/type), Middle 50% (n = 200 transponders/type), Bottom 25% (n = 50 transponders/type), and No Read (‘n’ varied depending on transponder type evaluated). Voltage response (VR) is defined as the amount of power, in volts (V), required by the transponder to transmit its 15 digit animal identification number (AIN) to a transceiver, also defined as the magnitude of wave oscillation when a transponder is modulating. Resonance frequency (RF) is the radio frequency, measured in hZ, at which a transponder responds (modulates) when transmitting its information. Low-frequency ISO 11785 (ISO, 1996b) transponders must communicate with transceivers at 134.2 $\pm$ 3 kHz to comply with conformance standards set forth by the International Committee for Animal Recording (ICAR, 2007). Resonance frequency and voltage response were determined by two blinded evaluators and all transponders were tested in duplicate. The resonance frequency and voltage response data was analyzed using PROC GLM of SAS including the main effects of transponder type, category and their interaction.

The 200 transponders/type from the Middle 50% were also tested for read rate (n = 1,200). Read rate is defined as the number of successful interrogations of each transponder divided by the number of opportunities for interrogation to occur. Read rate was collected on the three previously used transceivers, Allflex (SN 204404902), Edit ID (SN OG159001), and Destron (SN 063001) (Table 2.1). Transponders were subjected to evaluations of speed (1 m/sec and 3.05 m/sec) and orientation (parallel and perpendicular). Four combinations of evaluation were possible:

- Parallel orientation at 1 m/sec
- Parallel orientation at 3.05 m/sec
- Perpendicular orientation at 1 m/sec
- Perpendicular orientation at 3.05 m/sec

Each transponder was allowed 100 opportunities to be interrogated for each combination. All transceivers were mounted on a wooden stand located in the middle both vertically and horizontally of the middle flywheel on the trolley. Transceivers were positioned at a distance of 60 cm from the trolley. Sixty cm is the minimum distance a transponder should be successfully interrogated by a transceiver according to recommendations by the US Animal Identification Plan Bovine Standards Subcommittee (2004).

The GENMOD procedure of SAS was used to evaluate read rate. A predicted read rate was generated using a prediction model which accounted for effects of transponder type, transceiver, orientation and speed. The predicted read rate provides the probability that a transponder will be successfully interrogated.

A subset of sixty transponders were selected, based on superior predicted read rate and conformance to ISO 11785 (ISO, 1996b) and ICAR guidelines (ICAR, 2007), for use in evaluation of transceivers. Those transponders, within a type, had the greatest predicted read rate and whose resonance frequency met the 134.2 $\pm$ 3 kHz requirement.

All transponders previously evaluated for resonance frequency, voltage response and read rate in the “Middle 50%” were applied to cattle at either a livestock auction market or feedlot processing and then read through a panel transceiver system. All calves were shipped to the same feedlot and upon departure for harvest were read through the permanent panel transceiver system installed at the feedlot. The calves were harvested at four different abattoirs and transponders were read at this final location as well. Tags were removed from the ears after reading at the abattoir and returned to Kansas State University where they were interrogated a final time with a handheld RFID transceiver. This portion provided the final step in a full understanding of transponder performance in both laboratory and real-world production environments.

After transponder testing had begun and through communication with transponder manufacturers it was determined that the population of Temple transponders possessed two different chips. This determination could only be made by evaluation of the AIN. The Temple transponders with the EM Microelectronic chip had AIN numbers 98512… while the Temple transponders with the Phillips HiTag S chip had AIN numbers 98515…. Due to the late discovery of this difference the previously collected data was evaluated retrospectively and the two types of Temple transponder separated out. The sum of Temple transponders evaluated in each experiment provides the same value as other transponder types. Of the 500 total Temple transponders, 75 contained the Phillips® HiTag S chip while the remaining 425 transponders contained the EM® Microelectronic chip.

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Figure 2.1 Experimental design for selection of transponders used to test transceivers.

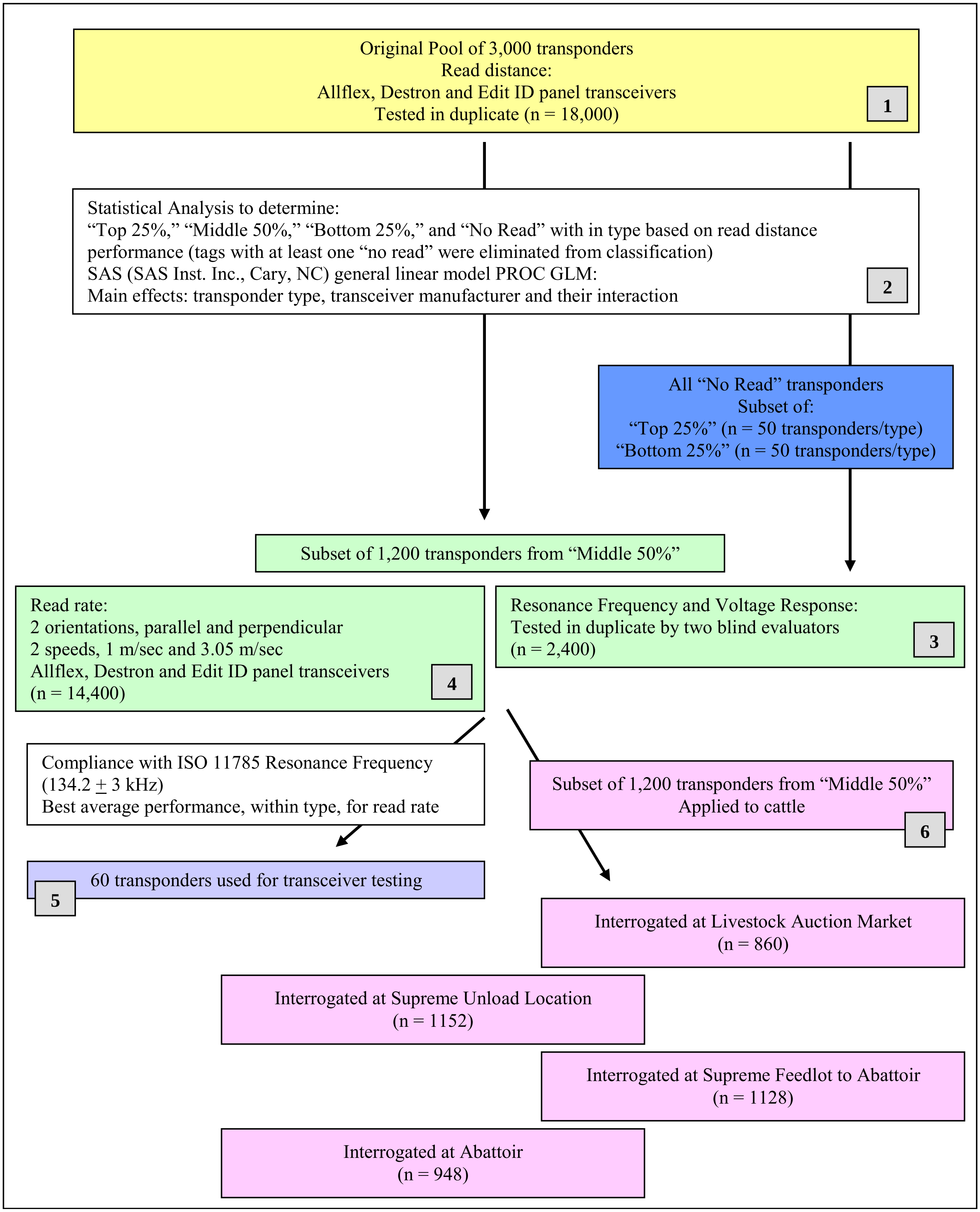

Figure 2.2 Representative pictures of transponder types used throughout studies. Top row (L to R): Farnam FDX, Y-Tex FDX, Allflex HDX. Bottom Row (L to R): Destron FDX (showing both sides; includes metal washer), Allflex FDX, Temple FDX (showing both sides; no metal washer). The two populations of Temple transponders used in this study (Temple HiTag chip and Temple EM chip) are visually identical but contain different chips.

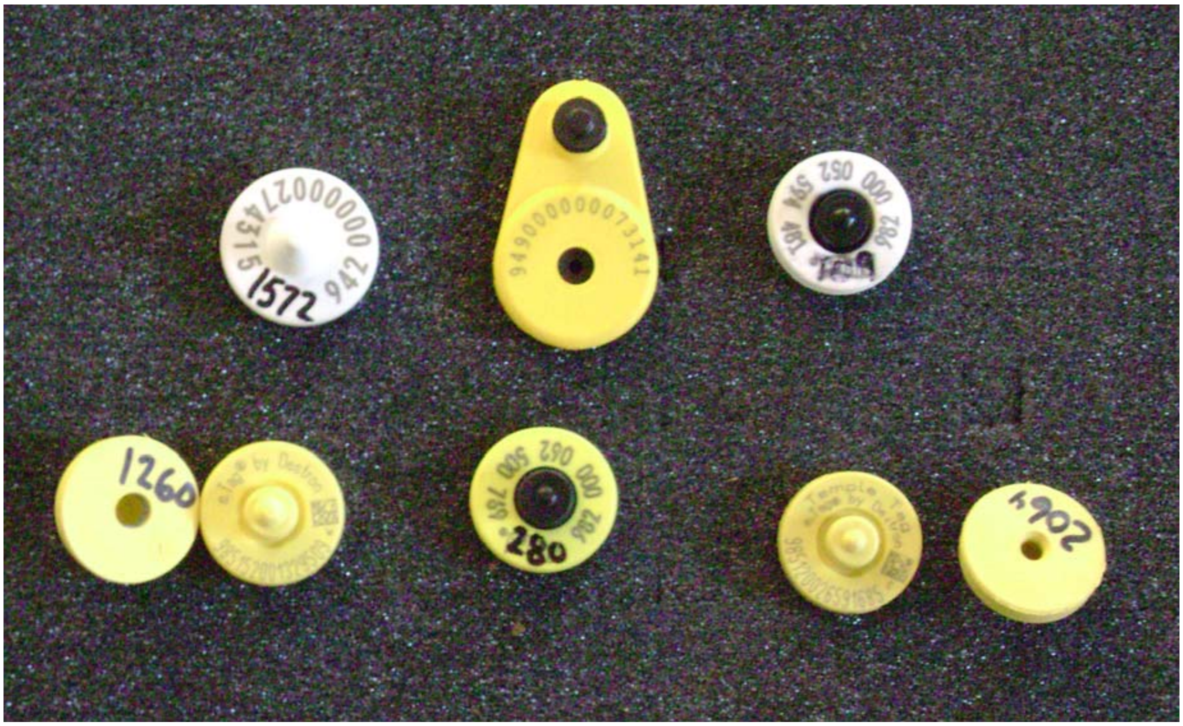

Table 2.1 Transceiver manufacturers and antenna panel dimensions transceiver systems used for transponder testing.

Transceiver Name	Manufacturer	Antenna Panel Dimensions (used in this research)	Panel Serial Number
Allflex	Allflex USA, Dallas, TX	61 x 40.6 x 2.5 cm	204404902
Destron	Destron Fearing, St. Paul, MN	58.4 x 45.7 x 2.5 cm	0601U2534
Edit ID	Edit ID Auckland, New Zealand	83.8 x 63.5 x 2.5 cm	OE-115-103

CHAPTER 3 - Impact of resonance frequency and voltage response on efficacy of low-frequency radio frequency identification transponders

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Abstract

A total of 1,993 low-frequency transponders representing both full-duplex (FDX-B) and half duplex (HDX) air interface technologies (Allflex FDX-B, n = 382; Allflex HDX, n = 300; Destron FDX-B, n = 377; Farnam FDX-B, n = 306; Temple (EM chip) FDX-B, n = 273; Temple (HiTag chip), n = 48; and Y-Tex, n = 307) were evaluated for resonance frequency (RF) and voltage response (VR). Transponders were separated into one of four classifications: Top 25% (n = 300), Middle 50% (n = 1,200), Bottom 25% (n = 299), and No Read (n = 190), based on previous read distance performance. Four of the selected transponders were determined to be dead upon evaluation of VR. Voltage response is the amount of power, in volts (V), required by the transponder to transmit its 15 digit animal identification number to a transceiver, or the magnitude of wave oscillation when a transponder is modulating. Resonance frequency is the radio frequency, measured in hZ, at which a transponder responds, or modulates, when transmitting its telegraph contents. Low-frequency ISO 11785 transponders must be designated to communicate with transceivers at 134.2 ± 3 kHz in order to comply with the conformance standard set forth by the International Committee for Animal Recording (ICAR). Measurement of RF identified those transponders which met the ICAR standard. Transponder type and category interacted to affect resonance frequency ($P < 0.0001$) and voltage response ($P < 0.0001$) of transponders. Three transponder types in the "Bottom 25%" category did not meet the minimum requirement of 131.2 kHz; the Allflex FDX-B (131.01 kHz), Farnam (131.03 kHz) and Y-Tex (128.94 kHz) RF are below the standard. Read distances are longer when transponders have RF closer to 134.2 kHz. Finally, a tendency is noted for a longer read distance when transponders have a lower VR.

KEYWORDS: Electronic identification, transponder, cattle, ISO 11785

Introduction

Electronic identification (eID) of livestock has been investigated recently (Wallace et al., 2007; Basarab et al., 2006; A. Bryant unpublished data, 2007) because it is gaining attention as a means of individual identification, allowing producers to better manage their livestock and to meet requirements for export markets that require verification programs. Low-frequency radio frequency identification (RFID) which complies with ISO 11784 and ISO 11785 has been recommended by the United States Animal Identification Plan (USAIP) bovine standards subcommittee as a means of individual electronic animal identification (USAIP, 2004).

While a number of manufacturers of ISO 11784 and ISO 11785 compliant transponders exist, not all transponder types have comparable levels of performance (Wallace, 2007; Bryant, 2006). According to the USAIP (2004), transponders should be capable of being interrogated at a distance equal to or greater than 60 cm. Based upon previous studies conducted in our laboratory we understand that a number of factors contribute to successful interrogation of transponders including resonance frequency and transponder metrics which includes chip and the copper coil for the antenna. ICAR (2007) requires ISO 11785 transponders to communicate at a resonance frequency of 134.2 $\pm$ 3 kHz for compliance.

Resonance frequency (RF) and voltage response (VR) were evaluated. A. Bryant (unpublished data, 2007) found that the two transponders with RF outside the ICAR standard range were the two transponders with the shortest read distance. Moreover, results from A. Bryant (unpublished data, 2007) indicate that RF and VR are affected by transponder type ($P < 0.0001$). Transponders were separated into categories based upon previous performance on read distance tests RF and VR were subsequently evaluated. The objective was to determine the influence of category on RF and VR variables and to determine if RF or VR variables were related to read distance measurements.

Materials and Methods

Read distance

Three-thousand transponders were acquired through normal distribution channels. Individual manufacturers were not contacted directly (Table 4.5). Figure 3.1 depicts the testing procedures deployed for the selection of transponders for RF and VR evaluation. Transponders were obtained from an original pool of 500 transponders per type (n = 3,000 transponders). The

3,000 transponders were tested in duplicate for read distance performance using three transceivers from different manufacturers.

Read distance is the distance away from the transceiver that a transponder is first successfully interrogated. Measurement of read distance was accomplished through the use of a trolley device to minimize variation in measurement due to human error. Each of the stationary transceivers was mounted to a wooden stand presenting the center of the transceiver, approximately 115 cm from the floor, to the transponder on the trolley. All transponders were presented in the parallel orientation to the transceiver (the face of the transponder approached the middle face of the transceiver) via a wooden cradle. The transponders were presented starting 152 cm away from the transceiver. A battery powered electric motor was mounted to the opposite end of the trolley from the transceiver. When operator-activated by the toggle switch, a rubber belt with Velcro pieces moved the cradle and transponder toward the transceiver for interrogation. Successful interrogation was determined by an audible generated from the computer when the AIN from the transceiver, as defined by ISO standard 11784 (ISO, 1996a), was automatically recorded in a Microsoft Excel® spreadsheet. Upon successful interrogation of the transponder, the operator terminated the power to the trolley. The read distance was then measured by the operator based on the location of the transponder in relation to a measuring tape mounted to the same plywood along which the rubber belt ran. The distance was then recorded next to the AIN number in the MS Excel file and in a data book.

Transponders were evaluated for read distance against three transceivers, Allflex® (SN 204404902), Edit ID® (SN OG159001), and Destron® (SN 063001) (Table 4.4), in duplicate. Read distance performance of each transponder was determined by the mean of duplicate tests on each transceiver. The mean read distance for each transponder and transceiver combination was then ranked from least to greatest. The read distance rankings of each transponder and transceiver combination were averaged to obtain a mean read distance rank within transponder type. Within a transponder type, the mean read distance rank was used to categorize each transponder into a "Bottom 25%", "Middle 50%" or "Top 25%" category as a measure of relative performance of read distance. Fifty transponders were randomly selected from the Bottom 25% and Top 25% categories for resonance frequency and voltage response evaluation. Two-hundred transponders were randomly selected from the Middle 50% category for resonance frequency and voltage response evaluation. Transponders in the "No Read" category consisted of any transponders that were not successfully interrogated at least once by the Destron, Allflex, or Edit ID readers during read distance testing.

Resonance Frequency and Voltage Response

Voltage response is the amount of power, in volts (V), required by the transponder to transmit its 15 digit AIN telegraph to a transceiver, or the magnitude of wave oscillation when a transponder is modulating. Resonance frequency is the radio frequency, measured in hZ, at which a transponder responds or modulates when transmitting its information. Low-frequency ISO 11785 (ISO, 1996b) transponders must communicate with transceivers at 134.2 $\pm$ 3 kHz to comply with the conformance standard set forth by the International Committee for Animal Recording (ICAR, 2007).

Equipment used to measure the voltage response and resonance frequency were an oscilloscope (Tektronix, Beaverton, OR, TDS 3024B four channel color digital phosphor oscilloscope, e*Scope®, 200MHz, 2.5 GS/s), function generator (Tektronix, Beaverton, OR, AFG 3021 single channel arbitary/function generator, 250 MS/s, 25 MHz), three antenna cables, and a probe (designed and built by radio frequency engineers at Destron Fearing, St. Paul, MN).

The measurements obtained by this method are specific to this exact setup and cannot be duplicated due to the specific individual characteristics of the probe; any slight variation from this probe will result in different measurements. The relative differences in measurements between probes would still be apparent although exact values will likely differ.

RF and VR transponder parameters were collected using the protocol described and used in Appendix B. RF and VR were determined by one of two evaluators and all transponders were tested in duplicate. The testing protocol was designed such that the individual transponder type identities were not known to the evaluator during testing. If no resonance activity was detected from the transponders they were designated "dead" when evaluated for resonance frequency and voltage response, and were therefore removed from the data set prior to statistical analysis. No Allflex HDX transponders had a single "no read" during read distance analyses. No Temple (HiTag chip) transponders are in the Bottom 25% category because categorization based on read distance performance occurred before the two populations of chips contained within the Temple tags were sorted out.

The entire RF and VR evaluation protocol is located in Appendix B.

Laboratory Environment

The laboratory environment was previously inspected for electromagnetic interference using a Tektronix® (Beaverton, OR) WCA280A Wireless Communications Analyzer. The inspection was conducted by a Kansas State University (KSU) Animal Identification Knowledge Laboratory technician trained by the KSU Electronics Design Laboratory according to the protocol developed by Bryant et al. (2006). The environment was determined to be free of electromagnetic interference at 134.2 $\pm$ 25 kHz and -130 to -30 dBm, the frequency band that could interfere with the functionality of low-frequency RFID transponders and transceivers.

Statistical Analysis

The RF and VR data were analyzed using a general linear model of PROC GLM in SAS including the main categorical effects of transponder type, category (Top 25%, Middle 50%, Bottom 25% and No Read) and their interaction. A p-value of < 0.05 was used to determine significant differences.

Results and Discussion

Resonance Frequency

Transponder type and category ("Top 25%," "Middle 50%," "Bottom 25%," and "No Read") interacted to affect the RF of transponders ($P < 0.0001$). A. Bryant (unpublished data, 2007) also noted that transponder type affected RF ($P < 0.0001$). Therefore, transponders can be selected for a RF close to 134.2 kHz. Table 3.1 provides a comparison of transponder type within an "average read distance rank" category. Figure 3.2 provides a comparison of RF across categories for transponders within a transponder type.

Transponders in the "Bottom 25%" category that failed to meet ICAR requirements for RF include Allflex FDX-B (131.01 kHz), Farnam (131.03 kHz) and Y-Tex (128.94 kHz). The Y-Tex transponder also failed to meet ICAR RF requirements in the "Middle 50%" and "No Read" categories, with RF 130.0 kHz and 130.6 kHz, respectively. The Y-Tex transponders retained short read distances when interrogated prior to categorization. There is a relationship between read distance and RF. Those transponders with RF closer to 134.2 kHz will be successfully interrogated at a longer distance.

Those transponders in the "Top 25%" category based on average read distance rank had mean RF closest to 134.2 kHz as compared with other categories ($P < 0.05$). Allflex HDX and Temple (HiTag chip) transponders are the exception as the mean RF for these transponders was near 134.2 kHz for all categories. The RF and communication system for the HDX transponders likely contributed to no difference in category RF. As noted previously, there is a relationship for most transponders between a long read distance and a RF close to 134.2 kHz. This relationship is in agreement with unpublished data from A. Bryant (2007) which notes that those transponders with poorer read distances had RF further away from 134.2 kHz.

Voltage Response

Transponder type and category ("Top 25%," "Middle 50%," "Bottom 25%," and "No Read") interacted to affect the VR of transponders ($P < 0.0001$). A. Bryant (unpublished data, 2007) noted that transponder type affected VR measurements ($P < 0.0001$). Table 3.2 provides a comparison of transponder type within an "average read distance rank" category for VR. Figure 3.3 provides a comparison of VR across categories for transponders within a transponder type.

Across all average read distance rank categories, the Farnam transponders had the lowest mean VR while Destron transponders had the highest mean VR (Table 3.2). For Allflex FDX-B, Destron and Y-Tex transponders a lower VR was observed as the read distance increased; transponders in the "Top 25%" had significantly lower VR than other categories ($P < 0.05$). For Farnam and Temple (EM chip) transponders in the "Top 25%" category VR was lower than transponders classified in the "Bottom 25%" ($P < 0.05$) category and was similar to "Middle 50%" categories. The Allflex HDX and Temple (HiTag chip) transponders did not have different VR when comparing average read distance rank categories. These results suggest an inverse relationship between VR, power in volts required by a transponder to transmit its AIN, and read distance within a transponder type. Logically, transponders that require more power to charge and transmit their AIN would require more time to become activated which would negatively impact read distance as the transponder is approaching the transceiver at a constant rate. This only holds true within a transponder type as the Farnam transponder, with the lowest VR, does not have the greatest read distance of all transponders evaluated. While the Farnam transponder had the lowest VR it did not have RF closest to 134.2 kHz, which is known to impact read distance.

Regarding the "No Read" transponders, a difference was not observed for either RF or VR within a transponder type between the "No Read" and the "Middle 50%" categories. The qualification for "No Read" was one missed interrogation out of six opportunities. It is possible, for example, that while one opportunity was missed the other five interrogations were successful at a long read distance. The "No Read" transponders were likely dispersed throughout each of the other three categories and therefore would not have different RF or VR values.

Implications

Not all transponders meet ICAR conformance standards; those transponders with short read distances tend to have resonance frequencies further from 134.2 kHz, with some falling outside the 134.2 $\pm$ 3 kHz accepted deviation. An inverse relationship between read distance and voltage response was observed; a lower voltage response tended to provide transponders with longer read distances.

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Figure 3.1 Experimental design for selection of transponders tested for resonance frequency and voltage response.

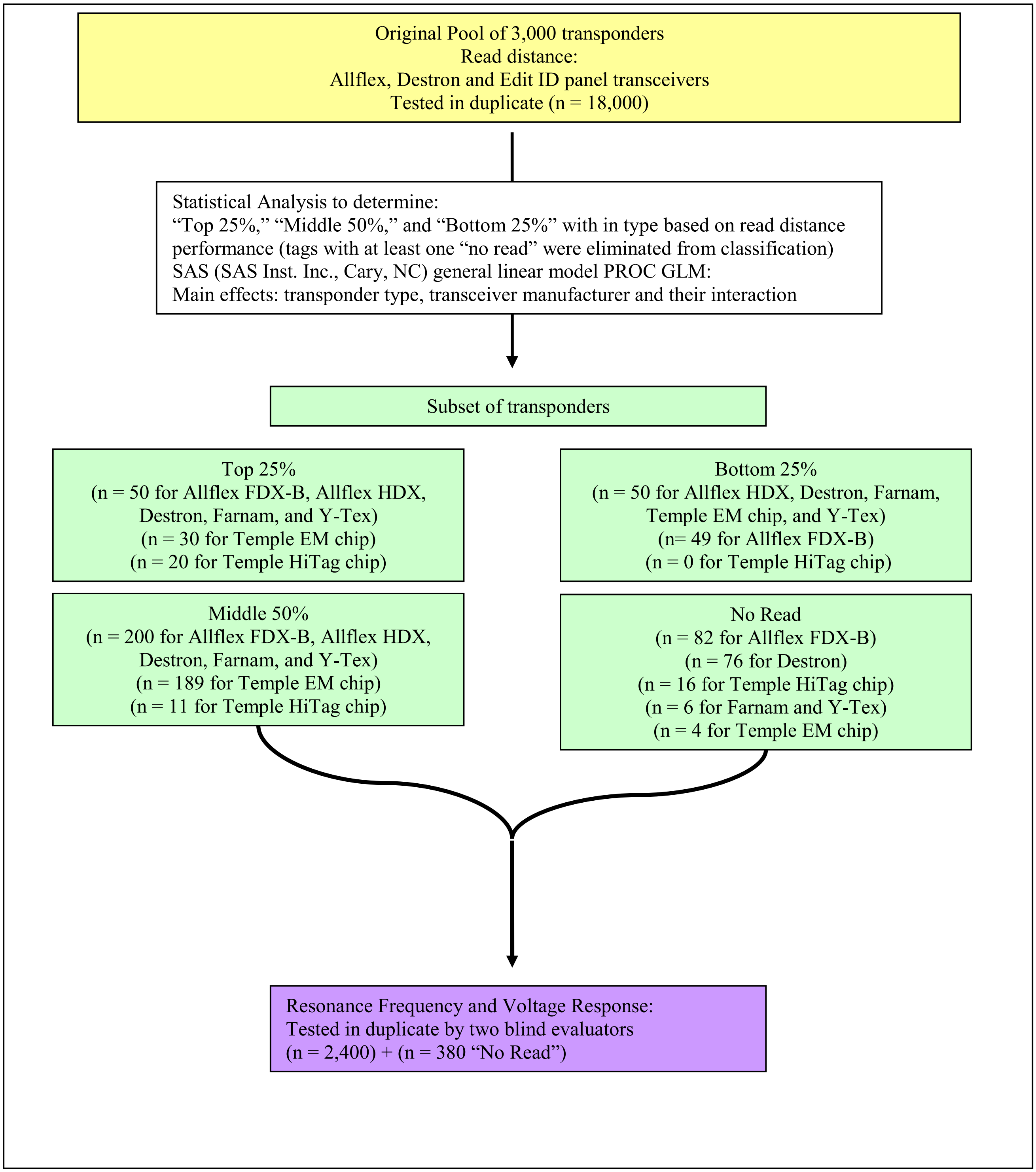


Table 3.1 Comparison of mean resonance frequencies of transponders from different manufacturers within mean read distance performance categories.

	Transponder Mean Read distance Rank Category								
		Resonance Frequency (kHz)							
	Dead	No Read		Bottom 25%		Middle 50%		Top 25%	
Transponder Type	**n**	**n**		**n**		**n**		**n**	
Allflex FDX-B	1	82	132.23[a]	49	***131.01[a]***	200	132.14[a]	50	132.66[a]
Allflex HDX	0	0	--	50	133.86[b]	200	133.91[b]	50	133.93[b]
Destron FDX-B	1	76	136.11[b]	50	136.81[c]	200	136.09[c]	50	135.55[c]
Farnam FDX-B	0	6	132.55[a]	50	***131.03[a]***	200	132.30[d]	50	133.07[d]
Temple FDX-B (EM chip)	0	4	133.79[c]	50	133.50[d]	189	133.97[b]	30	134.00[be]
Temple FDX-B (HiTag chip)	1	16	134.23[c]	0	--	11	134.24[b]	20	134.39[e]
Y-Tex FDX-B	1	6	***130.60[d]***	50	***128.94[e]***	200	***130.00[e]***	50	131.46[f]

Transponder type x Category interaction: $P < 0.0001$
Within a column, means with different superscripts differ ($P < 0.05$).
Bold denotes those values that fall outside of 134.2 $\pm$ 3 kHz, the required range for ISO 11785 and ICAR compliant transponders.

Table 3.2 Comparison of voltage responses of transponders from different manufacturers within mean read distance performance categories.

		Transponder Mean Read distance Rank Category							
		Voltage Response (V)							
	Dead	**No Read**		**Bottom 25%**		**Middle 50%**		**Top 25%**	
Transponder Type	**n**	**n**		**n**		**n**		**n**	
Allflex FDX-B	1	82	4.50^{a}	49	5.07^{a}	200	4.51^{a}	50	4.29^{a}
Allflex HDX	0	0	--	50	3.65^{b}	200	3.58^{b}	50	3.53^{b}
Destron FDX-B	1	76	5.24^{b}	50	5.39^{c}	200	5.23^{c}	50	5.02^{c}
Farnam FDX-B	0	6	1.47^{c}	50	1.53^{d}	200	1.42^{d}	50	1.36^{d}
Temple FDX-B (EM chip)	0	4	1.89^{c}	50	1.83^{e}	189	1.58^{e}	30	1.55^{e}
Temple FDX-B (HiTag chip)	1	16	3.51^{d}	0	--	11	3.68^{b}	20	3.54^{b}
Y-Tex FDX-B	1	6	3.03^{e}	50	4.13^{f}	200	3.98^{f}	50	3.41^{b}

Transponder type x Category interaction: $P < 0.0001$
Within a column, means with different superscripts differ ($P < 0.05$).

Figure 3.2 Comparison of resonance frequencies across mean read distance rank categories within transponder type. **Mean read distance rank category and transponder type interacted ($p<.0001$) to affect resonance frequencies, therefore resonance frequency comparisons across categories are made within transponder type.**

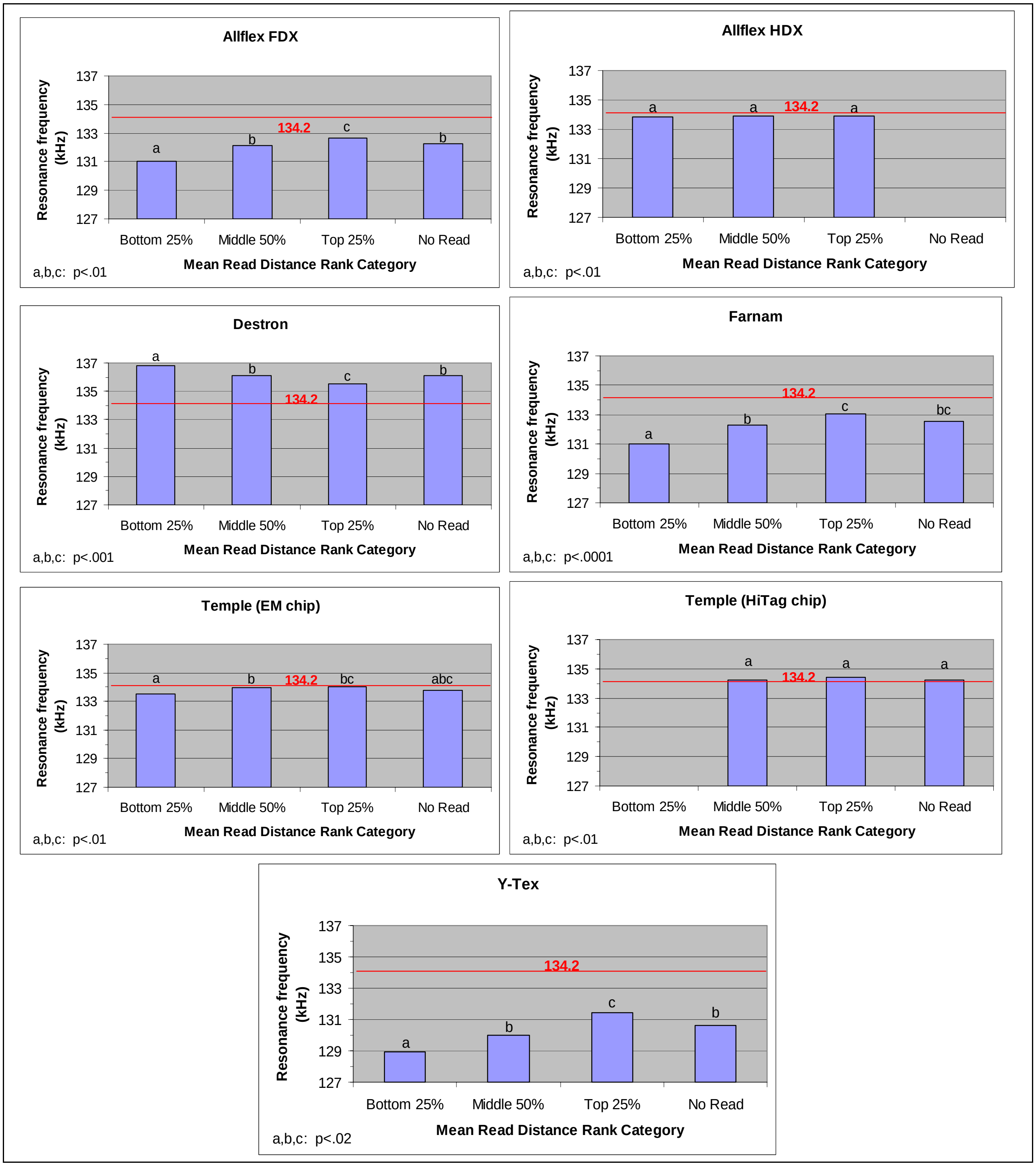
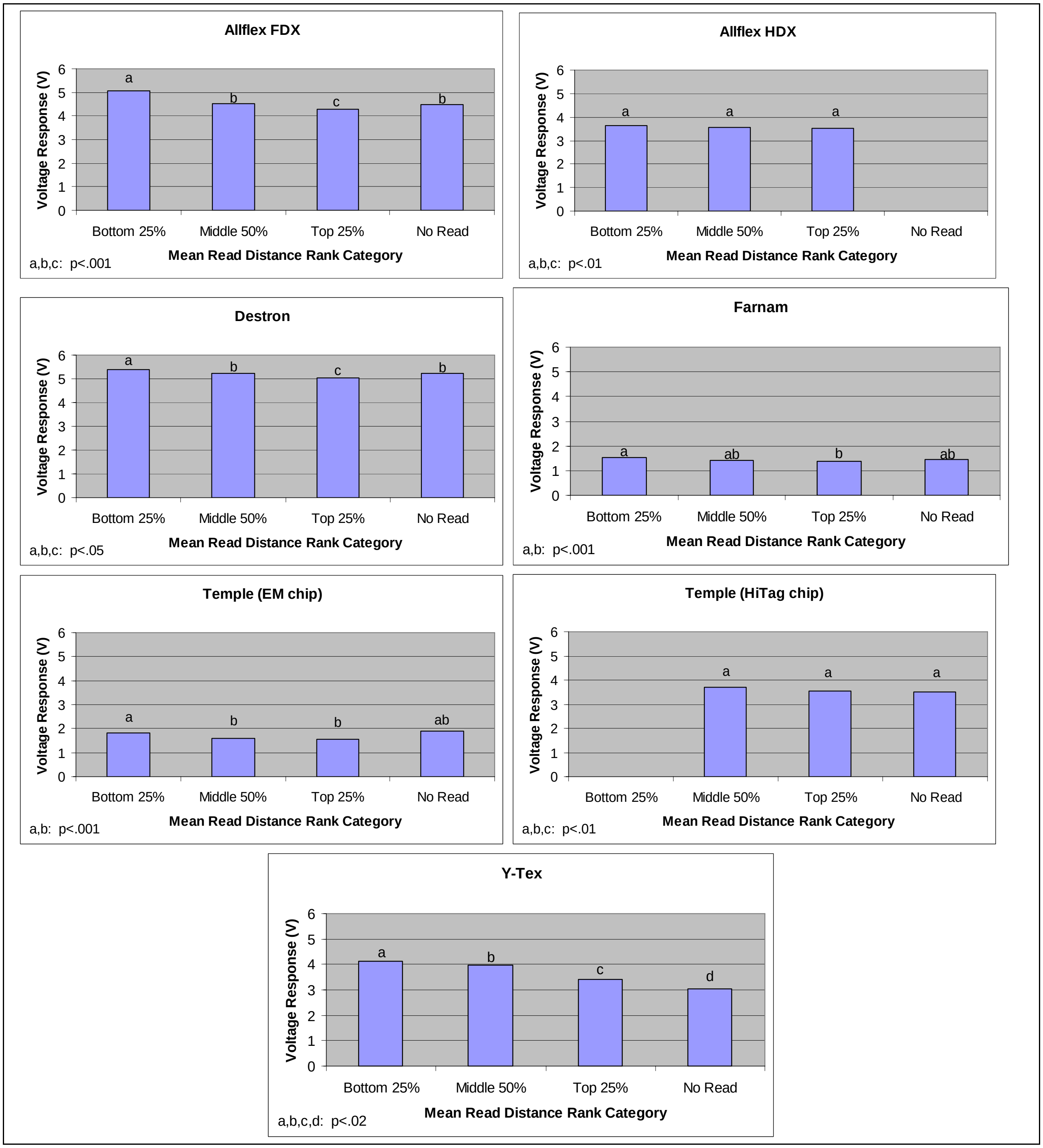


Figure 3.3 Comparison of voltage responses across mean read distance rank categories within transponder type. **Mean read distance rank category and transponder type interacted (p<.0001) to affect voltage responses, therefore voltage response comparisons across categories are made within transponder type.**



CHAPTER 4 - Read distance performance and variation of five low-frequency radio frequency identification panel transceiver manufacturers

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Abstract

The use of electronic animal identification technologies by livestock managers is increasing. However, the performance of these technologies when used in livestock production environments can be quite variable. This study was conducted to 1) determine if read distances of low-frequency radio frequency identification (RFID) transceivers are affected by manufacturer of the transponder being interrogated, 2) determine if read distance variation of low-frequency RFID transceivers is affected by transceiver manufacturer and 3) determine if read distance of various transponder and transceiver manufacturer combinations meet the 2004 United States Animal Identification Plan (USAIP) bovine standards subcommittee minimum read distance recommendation of 60 cm. Twenty-four transceivers (n = 5 transceivers/manufacturer for Allflex, Boontech, Farnam, and Osborne; n = 4 transceivers for Destron Fearing) were tested using 60 transponders (n = 10 transponders/type for Allflex FDX-

B, Allflex HDX, Destron Fearing FDX-B, Farnam FDX-B, and Y-Tex FDX-B; n = 6 for Temple FDX-B (EM Microelectronic chip) and n = 4 for Temple FDX-B (HiTag chip)) presented in the parallel orientation. All transceivers and transponders used met ISO 11784 and 11785 standards. Transponders represented both half-duplex and full duplex low-frequency air interface technologies. The use of a mechanical trolley device enabled the transponders to be presented to the center of each transceiver at a constant rate thereby reducing human error. Transponder and transceiver manufacturer interacted ($P < 0.0001$) to affect read distance indicating that transceiver performance was greatly dependent upon the transponder type being interrogated. Twenty-eight of thirty combinations of transceivers and transponders evaluated met the minimum recommended USAIP read distance. The mean read distance across all thirty combinations was 45.1 cm to 129.4 cm. Transceiver manufacturer and transponder type interacted to affect read distance variance ($P < 0.05$). Maximum read distance performance of low-frequency RFID technologies with low variance can be achieved by selection of specific transponder and transceiver combinations.

Key words: electronic identification, transponder, transceiver, cattle

Introduction

While the use of electronic animal identification (eID) technologies by livestock managers is increasing, the performance and reliability of RFID equipment has been identified as a concern (Breiner, et al., 2007). The USDA's proposed National Animal Identification System (NAIS) has also lead to increased discussion regarding implementation of eID. Additionally, the ability to trace cattle from birth to harvest with individual ID is important for export to other countries. To accomplish individual animal ID the use of RFID ear tags (transponders) and readers (transceivers) has been implemented as it provides a unique, permanent and tamper evident means of ID. This technology has been evaluated for application in swine (Blair et al., 1994; Babot et al., 2006; Santamarina et al., 2007), cattle (Blasi et al., 2003; Ghirardi et al., 2004; Basarab et al., 2006) and sheep (Edwards et al., 2001) as a means of effective ID.

The two low-frequency air interface technologies commonly used for animal ID include FDX-B and HDX, which conform to International Organization for Standardization (ISO) 11784 and ISO 11785 standards (ISO, 1996(b), 1996(a)). ISO 11785 requires transponders to communicate with transceivers at 134.2 $\pm$ 3 kHz and also outlines the requirements for transceiver conformance (ISO, 1996b; ICAR, 2007). While transceivers conform to standards, potential problems may arise with overall consistency of the product. Published literature does not provide research regarding read distance variation across transceiver manufacturers. The transceiver with the greatest read distance may not provide read distances with the least variance which would likely negatively impact the acceptability of this technology by livestock managers.

The USAIP bovine standards subcommittee (2004) for the NAIS recommended a minimum performance level by transponders of 100% readability at 60 cm from the transceiver at best orientation. There is a limited amount of published research (Wallace 2006; A. Bryant unpublished data, 2007) that evaluates transponder performance across multiple transceivers in a controlled laboratory environment. The objectives of this study were to 1) determine the extent of variation in read distance of RFID transceiver manufacturers by transponder type and 2) determine the effect of RFID transceiver manufacturer on read distance variance. Moreover, this study was conducted to provide further information to the USDA and cattle producers to assist in the understanding and implementation of this technology.

Materials and Methods

Two types of electronic transponders with two data transfer air interface technologies based on ISO 11785: HDX (n = 10) and FDX-B (n = 50) (ISO, 1996b) were used to evaluate transceiver performance. Five manufacturers of ISO 11785 compliant transceivers were evaluated. Twenty-four transceivers were tested for read distance and read distance variance with 60 different transponders. Twenty-four transceivers representing five manufacturers were tested (n = 5 transceivers/manufacturer for: Allflex, Boontech, Farnam, and Osborne; n = 4: Destron Fearing), [for descriptive characteristics see Table 4.4]. Seven types of low-frequency (ISO 11784 and ISO 11785) RFID cattle transponders from five manufacturers (n = 10 transponders/type for Allflex FDX-B, Allflex HDX, Destron Fearing FDX-B, Farnam FDX-B, and Y-Tex FDX-B; n = 6 transponders for Temple FDX-B (EM Microelectronic chip) and n = 4 transponders for Temple FDX-B (HiTag chip)) (Table 4.5) were presented to each of the transceivers for evaluation of read distance. Nine Allflex HDX transponders were used for evaluation of the Boontech transceivers as one Allflex HDX transponder was nonfunctional and subsequently removed from testing. All transponders and transceivers tested are commercially available beef to producers and have significant market share in the US animal identification industry.

Transponder Selection

Three-thousand transponders were acquired through normal distribution channels. Individual manufacturers were not contacted directly. Figure 4.1 depicts the testing procedures for selection of the sixty transponders used for transceiver testing. Sixty selected transponders were obtained from an original pool of 500 transponders per type (n = 3,000 transponders). The 3,000 transponders were tested in duplicate for read distance performance on three different transceivers. Data from this test was used to determine the middle 50% of transponders based on read distance performance. A random selection of 200 transponders per type was obtained and evaluated for read rate performance (n = 1,200 transponders). These 1,200 transponders were also tested for resonance frequency and voltage response. Only those transponders meeting the ISO 11785 standard for resonance frequency (134.2 ± 3 kHz) were eligible for further testing. The top ten transponders per type (n = 60 transponders) based on average read rate performance and conforming to the ISO 11785 standard were selected for use in the evaluation of transceiver performance. Transponders were selected based on these criteria to minimize variation in transceivers due to transponder performance, as the primary focus was evaluation of transceivers.

Transceiver Testing

Read distance is the distance from the transceiver when a transponder is first successfully interrogated. Transceivers were acquired through direct contact with individual manufacturers. Due to technical problems, one Destron Fearing transceiver was eliminated (n = 24 transceivers) from analyses. Measurement of read distance was accomplished through the use of a trolley device to minimize variation in measurement due to human error (Figure 4.2). All stationary transceivers were mounted to a wooden stand presenting the center of the transceiver, approximately 115 cm from the floor, to the transponder on the trolley. All transponders were presented in the parallel orientation to the transceiver (the face of the transponder approached the middle face of the transceiver) via a wooden cradle. The transponders were initially presented 152 cm away from the transceiver. A battery powered electric motor was mounted to the opposite end of the trolley from the transceiver and when manually activated by an operator a rubber belt with Velcro stabilizing the cradle, moved the cradle holding the transponder toward the transceiver for interrogation. Successful interrogation was determined by an audible from the computer when the animal identification number (AIN) from the transceiver was automatically recorded into a Microsoft Excel® spreadsheet. Upon successful interrogation of the transponder, the trolley operator terminated the power to the trolley, stopping belt movement. The read distance was then measured by the trolley operator based on the location of the transponder in relation to a measuring tape mounted parallel to the plywood and the rubber belt. The range was then recorded next to the AIN number in the MS Excel file and in a data book.

Laboratory Environment

The laboratory environment was previously inspected for electromagnetic interference (EMI) using a Tektronix® (Beaverton, OR) WCA280A Wireless Communications Analyzer. The inspection was conducted by a KSU Animal Identification Knowledge Laboratory technician trained by the KSU Electronics Design Laboratory according to the protocol utilized by Bryant et al. (2006). The environment was determined to be free of EMI at 134.2 $\pm$ 25 kHz and -130 dBm to -30 dBm, the frequency range that might interfere with the evaluation of read distance test.

Statistical Analysis

A general linear model (PROC GLM) in SAS (SAS Inst. Inc., Cary, NC) including the main effects of transponder type, transceiver manufacturer and their interaction was used for evaluation of read distance. The Brown-Forsythe test was used to determine homogeneity of variance in read distance among transceiver manufacturers within transponder type. Within a transponder type, pair-wise comparisons of read distance variance of transceiver manufacturers were then determined. Statistical significance was determined to occur at $P < 0.05$. Within a transceiver manufacturer, a pair-wise comparison of read distance variance was determined. Statistical significance was determined to occur at $P < 0.05$.

Results and Discussion

Transceiver manufacturer and transponder type interacted to affect read distance variance ($P < 0.05$). When evaluating randomly selected transponders and a single transceiver per manufacturer, transponder type and transceiver manufacturer interacted to affect read distance (Bryant et al., 2006 and Wallace et al., 2006). Our data supports and further explains this data, noting that transceiver manufacturer performance is greatly dependent on transponder. Poor transceiver performance cannot be attributed to technical problems in the transponder because all equipment tested met ISO 11785 standard (ISO, 1996b).

The data from this study agrees with Bryant et al. (2006) which showed that a significant variation in read distance can occur between transceivers and that transceiver performance is dependent on transponder manufacturer. A significant interaction between transceiver manufacturer and transponder type affecting read distance was observed ($P < 0.0001$). The selection of transponder and transceiver combination can greatly impact the success of a system and increased acceptance of this technology by livestock producers.

According to the minimum read distance performance recommendations provided by the USAIP Bovine Standards Subcommittee (2004), a transceiver must consistently interrogate a transponder at a distance greater than 60 cm. Destron Fearing transceivers possessed the shortest read distance across all transponders evaluated, except when interrogating the Allflex HDX, with two transponder types being interrogated at less than 60 cm ($P < 0.05$). In contrast, Allflex, Boontech, and Farnam transceivers consistently interrogated all transponder types at 61 cm or more. The Boontech transceivers had the longest read distance on all transponders evaluated except when interrogating the Allflex HDX ($P < 0.05$). As increased implementation of electronic identification occurs, it is important that the transponder and transceiver combination meet minimum performance recommendations as these recommendations are being used when facilities are being designed.

The Y-Tex transponder had the shortest read distance across all transceiver manufacturers meeting the bovine working group recommendation of 60 cm on three of five transceiver manufacturers. The best transponder and transceiver combination was Boontech and Temple (EM chip) respectively, achieving a read distance of 129.9 cm ($P < 0.05$). In contrast, the shortest read distance combination was the Y-Tex transponder and the Destron Fearing transceiver, with a distance of 45.6 cm ($P < 0.05$).

Bryant (unpublished data, 2007) postulated that a manufacturer of transceivers might tune or design their product to successfully interrogate a specific transponder of the same manufacturer to have a greater read distance while still conforming to ISO standards. The Farnam transponder and transceiver manufacturer combination had the lowest variance in read distance ($P < 0.05$) but did not have the longest average read distance. The Allflex and Boontech transceivers interrogated the Allflex HDX tag at the longest read distance ($P < 0.05$) while having variances that were statistically second lowest to the Osborne transceiver, which had the second longest read distance ($P < 0.05$). When interrogating the Allflex FDX-B transponder, the Allflex transceivers had the greatest read distance variance ($P < 0.05$) and the second longest read distance ($P < 0.05$) which does not agree with results by A. Bryant (unpublished data, 2007). The Destron Fearing transceiver had the shortest read distance when interrogating the Destron Fearing transponder ($P < 0.05$) and this combination also had one of the greatest degrees of variance.

Variances in read distance of transceiver manufacturers within transponder type were unequal ($P < 0.05$). Not one transceiver manufacturer consistently had large or small read distance variances when interrogating one transponder type. The greatest variance occurred with the Destron Fearing transceiver and the Allflex HDX transponder at 75.39 cm^2. In contrast, the smallest variance occurred when the Osborne transceiver interrogated the Destron Fearing transponder with a variance of 2.34 cm^2. The Farnam transceiver had either numerically the lowest variance or was not statistically different than the lowest transceiver variance for all transponders, except Allflex HDX, interrogated. However, the Farnam transceiver did not consistently have long or short read distances across all transponders. As no one combination both maximized read distance and minimized read distance variance it becomes necessary to select the combination that best meets the criteria for a specific situation.

Within a transceiver manufacturer the variance of individual transceivers was determined. Variances in read distance of transceivers within a manufacturer were unequal ($P < 0.05$). Transceivers within a manufacturer varied ($P < 0.05$) and depending on manufacturer transceivers were either consistent or highly variable for read distance (Table 4.3). All transceivers by Boontech had similar read distance variance. The remaining transceiver manufacturers had two transceivers that were not different from each other and one other transceiver. For example, the Allflex manufacturer had one transceiver (#1) with read distance variance different than two transceivers (#2 and #3) but similar to the remaining two transceivers (#4 and #5). Overall, there is a difference in read distance consistency within a transceiver manufacturer; some transceivers have greater read distance variability than others. This can create a problem for purchasers of these products as one transceiver may not perform as well as another, when purchased from the same manufacturer.

Due to the amount of variation in transceiver performance across multiple manufacturers of transponders, there is a need for further analysis to provide producers with the most consistent combination of transponder and transceiver, thereby increasing the acceptability of the technology. Basarab et al. (2006) showed that the design of RFID reading systems for specific circumstances is also an important consideration prior to implementation. Additionally, minimum performance standards for transceiver performance need to be adopted to help prevent the large degree of variation currently observed in transceiver manufacturers. Providing livestock managers with products which work successfully in the field is imperative to implementation of NAIS and meeting export market requirements. The USAIP recommendation of 60 cm starts to set performance standards for transponders and transceivers. The 60 cm recommendation is based on application of this technology to livestock management scenarios and the feasibility of subsequent implementation. All food animal industries need to be provided with animal identification devices which work consistently across multiple manufacturers of transceivers.

Implications

A great deal of variation exists between animal identification transponders based on transceiver performance. The Boontech transceiver shows the greatest potential for consistent interrogation across all transponder types. Selection of transponder and transceiver combinations which maximize read distance and minimize read distance variance is possible and important for successful implementation of low-frequency RFID technology.

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Table 4.1 Comparison of mean read distance in cm between transponders and transceivers.

	Transponder Type Mean (cm)						
Transceiver Manufacturer	Allflex FDX-B	Allflex HDX[1]	Destron Fearing FDX-B	Farnam FDX-B	Temple (EM chip) FDX-B	Temple (HiTag chip) FDX-B	Y-Tex FDX-B
Allflex	97.1^{k}	120.1^{n}	94.4^{jk}	87.4^{i}	94.4^{jk}	105.2^{l}	67.7^{d}
Boontech	113.7^{m}	119.9^{n}	104.4^{l}	123.1^{o}	129.9^{p}	122.7^{no}	94.7^{jk}
Destron Fearing	68.1^{d}	77.2^{fg}	67.6^{d}	***56.5^{b}***	68.9^{de}	72.7^{fe}	***45.6^{a}***
Farnam	81.1^{h}	76.2^{f}	75.0^{f}	92.7^{j}	97.1^{k}	87.2^{i}	71.2^{e}
Osborne	79.7^{gh}	103.2^{l}	74.9^{f}	80.1^{h}	85.0^{i}	87.8^{i}	61.3^{c}

Means with different superscripts differ ($P < 0.05$).
Allflex HDX[1] n = 9 for Boontech transceiver testing.
Bold italic denotes those values that fall below 60 cm, the minimum read distance denoted as "acceptable" by USAIP bovine standards subcommittee working group.

Table 4.2 Comparison of read distance variation (cm^2) among transceiver manufactures within transponder type.

	Transponder Type Variance (cm^2)						
Transceiver Manufacturer	Allflex FDX-B	Allflex HDX[1]	Destron Fearing FDX-B	Farnam FDX-B	Temple (EM chip) FDX-B	Temple (HiTag chip) FDX-B	Y-Tex FDX-B
Allflex	29.51^{a}	13.54^{a}	21.44^{a}	31.12^{a}	23.37^{a}	32.41^{a}	17.88^{ab}
Boontech	6.38^{b}	13.00^{a}	5.16^{b}	51.03^{a}	43.79^{ab}	4.01^{b}	25.76^{a}
Destron Fearing	18.11^{a}	75.39^{b}	12.09^{a}	15.57^{b}	9.09^{c}	20.68^{a}	13.61^{bc}
Farnam	3.45^{c}	28.07^{c}	3.20^{bc}	10.19^{b}	6.45^{c}	4.934^{b}	8.36^{c}
Osborne	4.11^{bc}	3.23^{d}	2.34^{c}	51.94^{a}	49.78^{b}	3.40^{b}	27.28^{a}

Within a column, values with different superscripts differ ($P < 0.05$).

Allflex HDX[1] n = 9 for Boontech transceiver testing.

Table 4.3 Comparison of read distance variation (cm^2) within a transceiver manufacture.

	TRANSCEIVER VARIANCE (cm^2) (within a manufacturer)				
Transceiver Number	ALLFLEX	BOONTECH	DESTRON[1]	FARNAM	OSBORNE
1	76.73^{a}	64.41^{a}	61.60^{ab}	29.49^{a}	56.69^{a}
2	128.83^{b}	75.21^{a}	48.36^{ab}	56.36^{b}	55.19^{a}
3	155.40^{b}	72.09^{a}	38.25^{a}	35.64^{ab}	87.86^{ab}
4	102.72^{ab}	64.85^{a}	eliminated	30.20^{a}	71.55^{ab}
5	117.20^{ab}	63.07^{a}	69.44^{b}	38.84^{ab}	103.91^{b}

Within a column, means with different superscripts differ ($P < 0.05$)
DESTRON[1]: Reader 4 was eliminated from testing due to mechanical problems.

Table 4.4 Transceiver manufacturers and antenna panel dimensions for transceiver systems used in transceiver read distance and variance research.

Transceiver Name	Manufacturer	Antenna Panel Dimensions (used in this research)	Panel Serial Number
Allflex	Allflex USA, Dallas, TX	61 x 40.6 x 2.5 cm	206324006
Allflex	Allflex USA, Dallas, TX	61 x 40.6 x 2.5 cm	206324008
Allflex	Allflex USA, Dallas, TX	61 x 40.6 x 2.5 cm	206324001
Allflex	Allflex USA, Dallas, TX	61 x 40.6 x 2.5 cm	206324002
Allflex	Allflex USA, Dallas, TX	61 x 40.6 x 2.5 cm	206324009
Boontech	Boontech Pty Ltd, Kyneton, Australia	119.4 x 74.3 x 2.5 cm	12060013
Boontech	Boontech Pty Ltd, Kyneton, Australia	119.4 x 74.3 x 2.5 cm	12060006
Boontech	Boontech Pty Ltd, Kyneton, Australia	119.4 x 74.3 x 2.5 cm	12060009
Boontech	Boontech Pty Ltd, Kyneton, Australia	119.4 x 74.3 x 2.5 cm	07060018
Boontech	Boontech Pty Ltd, Kyneton, Australia	119.4 x 74.3 x 2.5 cm	12060010
Destron Fearing	Destron Fearing, St. Paul, MN	58.4 x 45.7 x 2.5 cm	063001
Destron Fearing	Destron Fearing, St. Paul, MN	58.4 x 45.7 x 2.5 cm	063201
Destron Fearing	Destron Fearing, St. Paul, MN	58.4 x 45.7 x 2.5 cm	063202
Destron Fearing	Destron Fearing, St. Paul, MN	58.4 x 45.7 x 2.5 cm	063804
Farnam	Farnam Companies, Inc., Phoenix, AZ	83.8 x 63.5 x 2.5 cm	OF-319-001
Farnam	Farnam Companies, Inc., Phoenix, AZ	83.8 x 63.5 x 2.5 cm	OF-319-005
Farnam	Farnam Companies, Inc., Phoenix, AZ	83.8 x 63.5 x 2.5 cm	OF-319-006
Farnam	Farnam Companies, Inc., Phoenix, AZ	83.8 x 63.5 x 2.5 cm	OF-319-009
Farnam	Farnam Companies, Inc., Phoenix, AZ	83.8 x 63.5 x 2.5 cm	OF-319-010
Osborne	Osborne Industries, Inc., Osborne, KS	121.9 x 61 x 1.9 cm	ASR700-000117
Osborne	Osborne Industries, Inc., Osborne, KS	121.9 x 61 x 1.9 cm	ASR700-000102
Osborne	Osborne Industries, Inc., Osborne, KS	121.9 x 61 x 1.9 cm	ASR700-000103
Osborne	Osborne Industries, Inc., Osborne, KS	121.9 x 61 x 1.9 cm	ASR700-000106
Osborne	Osborne Industries, Inc., Osborne, KS	121.9 x 61 x 1.9 cm	ASR700-000105

Table 4.5 Transponder product information: complete name, manufacturer and number range used in research.

Transponder Name	Transponder Name Specifics	Manufacturer	AIN range
Allflex FDX-B	Allflex FDX-B Lightweight Ultra Bovine EID Tag	Allflex USA, Dallas, TX	982000062137303 To 982000062501360
Allflex HDX	Allflex HDX High Performance Ultra EID Tag	Allflex USA, Dallas TX	982000050675179 To 982000055247867
Destron FDX-B	Destron FDX-B-B E. Tag®	Destron Fearing, St. Paul, MN	985152001329351 To 985152001342900
Farnam FDX-B	Farnam New Z Tag®	Farnam Companies, Inc., Phoenix, AZ	942000000261272 To 942000000470605
Temple FDX-B (EM chip)	Temple FDX-B Tamper Evident Tag (EM® Microelectronic chip)	Destron-Fearing, St. Paul, MN	985120025995527 To 985120026715145
Temple FDX-B (HiTag chip)	Temple FDX-B Tamper Evident Tag (Phillips® HiTag S chip)	Destron-Fearing, St. Paul, MN	985152000065926 To 985152000066600
Y-Tex FDX-B	Y-Tex ISO TechStar™ II FDX-B	Y-Tex Corporation, Cody, WY	949000000004671 To 949000000424453

Figure 4.1 Experimental design for selection of transponders used to test transceivers.

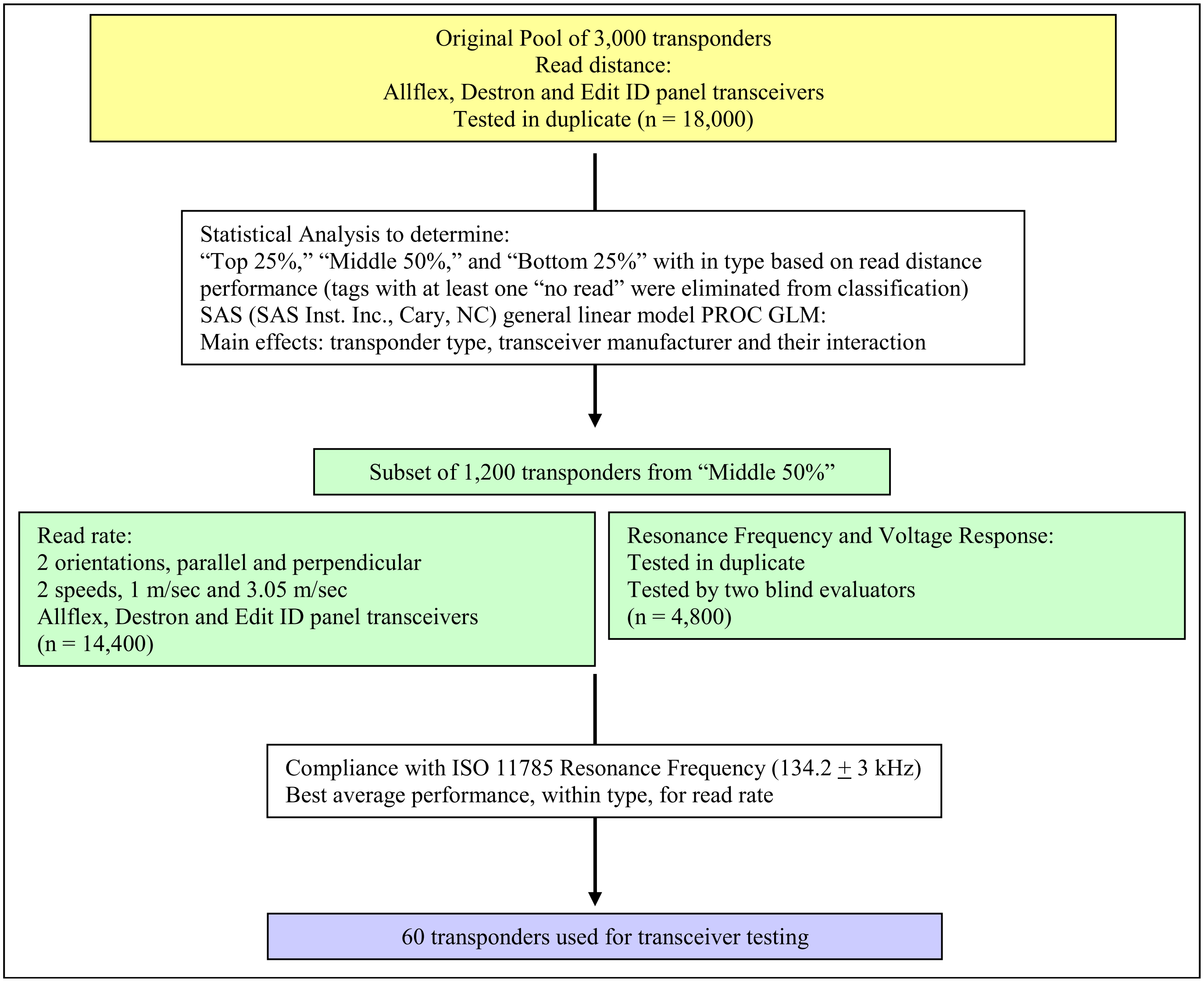
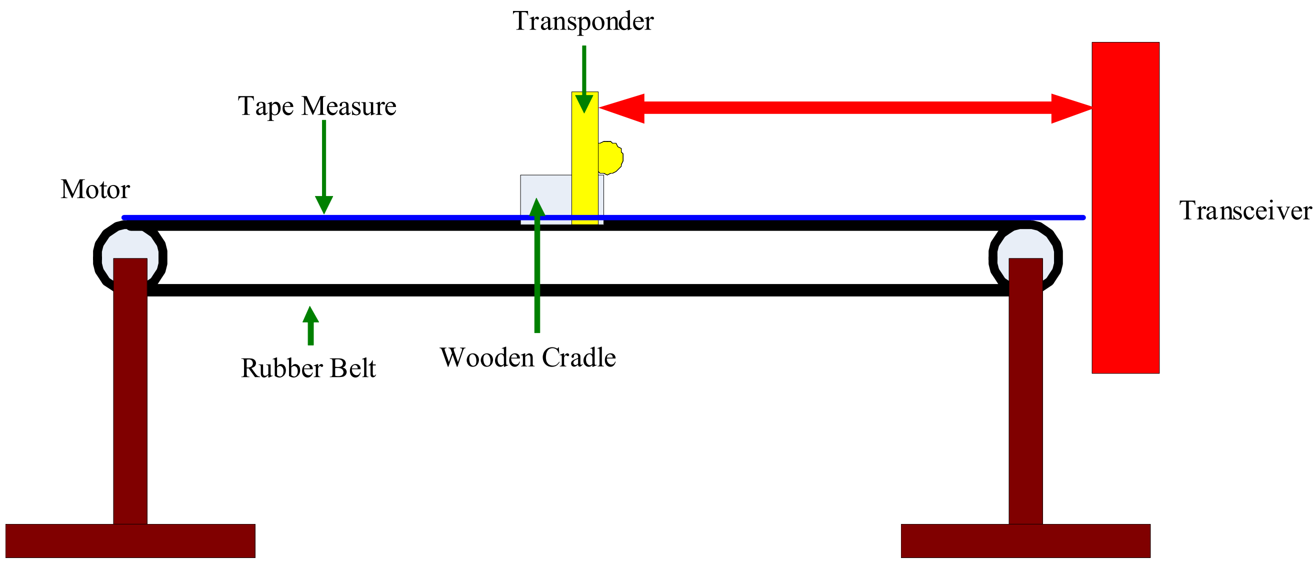


Figure 4.2 Trolley system used to obtain read distance measurements.



CHAPTER 5 - Evaluation of the occurrence of electromagnetic interference in livestock auction markets, commercial feedlots and cattle abattoirs

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Abstract

The increased use of electronic radio frequency identification (RFID) devices throughout the livestock industry has led to an increased need for understanding of the compatibility and conflict issues of these tools in the environments in which they are used. In general, the increased use of electronics and variable frequency drives increases the potential for interference which will decrease the effectiveness of an RFID system. The use of RFID in livestock production has increased; currently the most common radio frequency for animal identification is ISO 11785. The objective of this research was to characterize the incidence of electromagnetic interference (EMI) that may affect RFID transponder and transceiver function in livestock auction markets, feedlots and cattle abattoirs. EMI was evaluated in fourteen livestock auction markets, four commercial feedlots and five cattle abattoirs. A Tektronix® WCA280A Wireless Communications Analyzer was used to analyze the low-frequency spectrum. Specifically, the radio frequency band of interest was the spectrum of $\pm$ 25 kHz surrounding 134.2 kHz. Measurement of the potential interference or EMI signal strength was made using dBm, power in decibels in reference to 1 milliwatt. The amplitude range observed was -30 to -130 dBm. EMI was observed in all three production settings evaluated. In the livestock auction markets EMI was quite limited and was only observed at a level greater than -70 dBm at one market sale ring exit. In feedlots, EMI was observed primarily in processing barns at a level greater than -90 dBm, however EMI does exist in areas used to unload and load cattle. All four feedlots have some form of RFID equipment in place to read cattle tagged with low-frequency RFID transponders. Cattle abattoirs had the greatest amount of EMI of all three production settings evaluated. The strength and frequency of EMI varies within and among abattoirs. Three of the five abattoirs had low-frequency panel RFID transponder transceivers installed, two abattoirs noted having prior problems with the transceiver and one was generally satisfied overall with the performance of the transceiver currently installed. Now that EMI has been verified to exist in each of these production settings, there is a need to further evaluate the specific impact of EMI on transponder and transceiver function specific to low-frequency RFID.

KEY WORDS: cattle, electromagnetic interference, electronic identification

Introduction

Electromagnetic interference (EMI) occurs when electromagnetic waves from one electronic device obstruct the normal functions of another electronic device (de Sousa et al., 2002). The increased use of and advancements in radio frequency identification (RFID) have lent this technology to be potentially impacted by EMI. EMI has a negative impact on the ability of a RFID system to work effectively and poses a significant challenge to successful implementation of these systems in environments where animals are handled.

Porter et al. (2006) noted that the best performance of an RFID system is determined by the available transmitting power of the transceiver, the power available within the transponder to respond to the signal of the transceiver and environmental conditions, including EMI. Companies providing transponders and transceivers for livestock identification have noted that EMI can be a problem when installing and implementing a system. However, EMI in livestock production environments has not been previously quantified and published in a scientific literature. The recent use of Growsafe® Systems Ltd. in research has led to some discussion of potential EMI in some published studies, however exact quantification of potential problems still remains unanswered (Schwartzkopf-Genswein et al., 1999; DeVries et al., 2003). Our research object was to characterize the incidence of EMI affecting low-frequency RFID transponder and transceiver function in livestock auction markets, feedlot processing and load/unload facilities and cattle abattoirs.

EMI has been identified in other environments and its impact documented in published literature. For example, EMI can have significant effects on patients with implanted pacemakers and implanted cardioverter-defibrillators (de Sousa et al., 2002). EMI can impede the communication function of high performance integrated circuits, even at very low levels of EMI (Wang et al., 2006). There are a number of examples of EMI documentation at frequencies other than ISO 11785 the low-frequency of interest in this particular study.

Materials and Methods

EMI was evaluated in 15 livestock auction markets, 5 cattle abattoirs and 4 commercial feedlot processing facilities. The radio frequency band of interest is the spectrum of 134.2 kHz $\pm$ 25 kHz. This region was selected as it represents the low-frequency at which the transponders and transceivers conforming to ISO 11784 and 11785 communicate (ISO, 1996a, 1996b); the span represents those potential interferences that could have the greatest impact. Measurements of the level of potential interference were made using dBm, (power in decibels) referenced to 1 milliwatt. The amplitude of potential interference was observed at -30 to -130 dBm. Testing was completed using a Texas Instruments®-RFID stick antenna, part number RI-ANT-S02C, modified with a bayonet Neil-Concelman connector. For testing in the abattoirs and feedlots, the antenna was further modified with a 25 foot extension. A Tektronix WCA280A Wireless Communications Analyzer (SA) was used to analyze the frequency spectrum in the band of interest.

Throughout the duration of testing, expertise from the Kansas State University Electronics Design Laboratory (EDL) was utilized (T. Sobering, personal communication). The initial EMI testing at the Beef Stocker Unit was conducted by the EDL prior to the Animal Identification Laboratory's acquisition of a SA. They also assisted in environmental testing of the modular laboratory when it was installed. Validation of the SA purchased by the Animal ID Lab was also performed by EDL personnel.

A free run setting was used initially to observe any unusual characteristics in basal-level sideband noise. A "clean" environment, where no potential interferences can be observed, as determined by the free run is shown in Figure 5.1. In this environment, at the KSU Beef Stocker Unit, there are no visible signs of potential electromagnetic interference. In this figure the two peaks at 131.9 kHz and 129.1 kHz are signal created by the SA itself and do not represent EMI attributed to the environment. No other noises were observed above -125 dBm other than the two peaks that are considered a normal component of the equipment.

If "no interferences," "no potential interferences" or "clean environment" is noted we recognize that nothing is detected above -130 dBm. However, this does not necessarily mean that there are no interferences at all because they could exist at a lower dBm. We recognize the need to determine the potential effects of signal strength and frequency on function of ISO 11785 low-frequency RFID equipment, but at this point in time this information is unknown.

During testing, if observations on the free run screen were noticeably different than observed in a known clean environment the data was saved prior to starting trigger setting observations (State A or B). Observed data was also recorded in the data book. After observing the free run setting, a trigger setting (State A or B), which sets a minimum level of noise decibel that a potential interference must achieve to be considered consequential, was used for the assessing of potential interferences for the remaining evaluation period.

State A:

Span (x-axis): 134.2 ± 25 kHz

Frequency (y-axis): -30 dBm to -130 dBm

Trigger level set at -70 dBm.

If a noise occurs within the span and frequency that is -70 dBm or greater a trigger will be automatically recorded and saved by the SA. If no triggers are recorded then no triggers will be available to save. In the following notes "no triggers" indicates that no triggers were receive and/or recorded; therefore no noises were observed louder than -70 dBm.

State B:

Span (x-axis): 134.2 ± 25 kHz

Frequency (y-axis): -30 dBm to -130 dBm

Trigger level set at -90 dBm.

If a noise occurs within the span and frequency that is -90 dBm or greater a trigger will be automatically recorded and saved by the SA. If no triggers are recorded then no triggers will be available to save. In the following notes “no triggers” indicates that no triggers were received and/or recorded; therefore no noises were observed louder than -90 dBm.

A/D Overflow:

“A/D Overflow” occurs if the signal level increases too high or the reference level is set too low, over-voltage input may occur. If an over-voltage input occurs, the status indicator “A/D OVERFLOW” is displayed in the red box. Note: If “A/D OVERFLOW” is displayed, it indicates that the A/D converter inside the SA in the part of the dwonconverter is overloaded. In this case, data is still accurate.

Electromagnetic interference evaluation in 14 livestock auction markets throughout Kansas

Fourteen livestock auction markets throughout Kansas volunteered to cooperate and participate in this project. All barns were evaluated during the summer of 2006 (June 13 – July 26). All testing was conducted during a regularly scheduled sale. Observations were made at 3 sites at each location: unload, sale ring exit, loading (load).

Observation times:

Unload: 2 hours prior to start of sale, during pre-sale unloading time

Sale Ring Exit: 3 hours during sale, or as long as sale was in session (whichever occurred first)

Load: 2 hours after sale ring exit evaluation, during peak load time

In each location in the auction market notes and observations were made of the lighting, fencing materials, location of auction block, number of vehicles, antennas, TV/computer monitors, lighted display boards, PA loud speaker systems, and use of equipment (cattle prod, machinery). Specific information for each livestock auction market is noted within its section.

Note: If data other than that which is observed in a clean environment was found then the information from the free run was saved and documented in the data book. If only a clean environment was observed data collection occurred using the -70 dBm trigger setting, without saving a free run.

Upon completion of each trigger setting time allocation a free run was observed to note if any new interferences occurred throughout the duration of testing. If present, this free run data was saved and noted in the data book.

The protocol for evaluation procedures is provided in Appendix C.

Electromagnetic interference evaluation in 4 commercial feedlots throughout Kansas

Four feedlots throughout Kansas agreed to participate in this project. The four participating feedlots were: Supreme Cattle Feeders, LLC (Agri Beef Co.), Great Bend Feeding Inc., Knight Feed Yard, and Ward Feed Yard, Inc. All feedlots were evaluated during the fall of 2007 (October 24 – November 8). All testing was conducted during regularly scheduled processing. Observations were made at 3 sites: unload, cattle processing chute/area, load.

Observation times:

Unload: 2 hours

Processing: 2 hours during processing, or for entire processing time (whichever occurred first)

Load: 2 hours

Note: If data other than that which is observed in a clean environment (see Figure 5.1 and previous description) was found then the information from the free run state on the SA was saved and documented in the data book. If only a clean environment was observed data collection occurred using the -90 dBm trigger setting (State B) and a free run observation was also saved. During cattle processing the environment was observed with the SA for a period while no cattle were being processed to observe the environment with the least possible potential interference.

Upon completion of observation using the trigger setting, a free run was conducted to note if any new interferences occurred during the duration of testing. If interferences were present, this free run data was saved and noted in the data book.

The protocol for evaluation procedures is provided in Appendix C.

Electromagnetic interference evaluation in 5 abattoirs throughout Kansas and Nebraska

Five abattoirs throughout Kansas and Nebraska participated in this project. The five abattoirs include: Tyson Fresh Meats, Inc.: Finney County, KS and Emporia, KS; Cargill Meat Solutions: Schuyler, NE; and National Beef Packing Co.: Dodge City, KS and Liberal, KS. All abattoirs were evaluated during the summer and fall of 2007 (July 2 – October 19). All testing was conducted during regularly scheduled processing. Observations were made on the harvest floor at the location mostly likely to have an RFID transceiver installed or where one is currently in place. If a RFID transceiver was already installed it was turned off for the duration of testing.

Observation times and SA antenna orientations:

Primary orientation: SA antenna positioned to mimic an eID tag transceiver; 4 hours, in 1 hour increments or 200 triggers, whichever came first.

Left orientation: SA antenna positioned toward the left of the primary orientation: 1 hour or 200 triggers, whichever came first.

Right orientation: SA antenna positioned toward the right of the primary orientation: 1 hour or 200 triggers, whichever came first.

Opposite orientation: SA antenna positioned toward the opposite direction of the primary orientation: 1 hour or 200 triggers, whichever came first.

Three runs or replications of the seven data collection orientations were performed at each abattoir.

Order of observations: primary, primary, left, right, opposite, primary and primary (Figure 5.2). Before each hour of observation a five minute free run setting was observed in the new antenna orientation.

Upon completion of each run, after the last primary run, the SA antenna was moved around the testing area and measured on free run for 5 minutes to observe potential changes in interferences. The data was saved and observations were recorded in the data book.

Note: All data observed in the environment from the free run was saved and documented in the data book. Data collection occurred using the -90 dBm trigger setting following a free run.

All observations occurred while cattle were being harvested, the only times without cattle were either immediately prior to a shift starting or during a shift change. Each run covered either one or two shifts such that both shifts are represented and all runs combined cover two days (except Cargill Meat Solutions, which was only evaluated for one day, both shifts).

The protocol for evaluation procedures is provided in Appendix C.

Results and Discussion

Electromagnetic interference evaluation in the Animal Identification Laboratory – An example of the impact of EMI

A modular building that now serves as the Animal Identification Laboratory was placed in August 2006 to provide ample space for conducting animal identification technology research. This dedicated laboratory space was evaluated for potential environmental interferences prior to its use as a research laboratory. The EMI testing was conducted with a Tektronix® (Beaverton, OR) WCA280A Wireless Communications Analyzer with assistance from personnel at the Kansas State University Electronics Design Laboratory.

During initial testing, EMI was observed in the Laboratory. Through a series of step-by-step eliminations it was determined that the existing light fixtures/ballasts were the cause of the EMI. Figure 5.3 depicts the initial evaluation with interference at 132 kHz, -97 dBm. In contrast, the clean environment is shown in Figure 5.4. Using the read distance test the interrogation distances of five randomly selected transponders were determined. Comparison of read distances in the two environments (lights on and lights off with the original ballast) is presented in Table 5.1. The transponders were interrogated using the Allflex panel transceiver (serial number 206324009).

The ballasts were replaced and subsequent evaluation of the environment with the SA was performed. Figure 5.5 depicts the environment with new ballasts and lights turned on. Basal interference level observed is below -125 dBm. Subsequent read distance testing conducted with lights on and off did not reveal a significant impact of lighting (on or off) on read distance.

This provides a “real-world” example of the potential impact of EMI on low-frequency RFID equipment function (ie. read distance). One concern in extrapolating these observations of EMI to other situations is that we do not know the proportional impact of the interference frequency (132 kHz) and signal strength (-97 dBm) on function of RFID equipment. For example, would the same signal strength (-97 dBm) at a frequency further from the low-frequency RFID communication frequency of 134.2 kHz (ie. 120 kHz) not impact RFID equipment function at all? Alternatively, a very weak signal (ie. -120 dBm) at 134 kHz may dramatically impact RFID equipment function.

These observations illustrate the need for additional research evaluating the impact of known EMI on RFID equipment function. It is also clear that the interpretation of trigger setting data collected regarding the characterization of potential EMI existing in livestock auction markets, feedlots and cattle abattoirs is limited to the signal strength thresholds (-30 to -70 or -90 dBm) we used for trigger level settings. The observations conducted when the trigger setting was used on the SA will allow us to isolate and select interference signal strengths and frequencies of interest on which to conduct further research.

Electromagnetic interference evaluation in 15 livestock auction markets throughout Kansas

Rezac Livestock Commission Company, Inc. of St. Marys, Kansas is located in the northeast region of the state and in 2006 marketed approximately 70,000 head of cattle. On June 13, 2006 observations and EMI measurements were taken. No potential interferences within the spectrum of interest were observed in any of the three locations. Therefore, this site was designated a clean environment. For observations of the materials and equipment in the area see Table 5.2.

Fort Scott Livestock Market, Inc. of Fort Scott, Kansas is located in the southeast region of the state. In 2006 approximately 89,800 head of cattle were marketed through this auction market. On June 17, 2006 observations and EMI measurements were taken. Throughout the day no noise interferences within our spectrum of interest were collected indicating a clean environment. The observations of materials and equipment in each area scanned are provided in Table 5.3.

Holton Livestock Exchange, Inc. located in Holton, Kansas in the northeast region of the state marketed approximately 41,000 head of cattle in 2006. On June 20, 2006 observations and EMI measurements were taken at two locations in the facility. At the unload/load location no potential noise interferences were observed, indicating a clean environment. At the exit of the sale ring during initial observations and scanning with the free run setting four peaks were observed as the SA antenna was moved within close proximity of a TV monitor (Figure 5.9). At approximately six inches from the TV monitor four strong peaks were observed, see Figure 5.6. Two intentional triggers were observed with State A running when the SA antenna was put within 6 inches of the TV monitor (Figure 5.7). However, when the antenna was setting on the stand for the duration of testing no triggers were recorded (Figure 5.8). For a complete list of observations of electronics and equipment see Table 5.4.

Manhattan Commission Company of Manhattan, Kansas is located in the northeast region of the state and marketed approximately 75,700 head of cattle in 2006. Observations of EMI were taken on June 23, 2006. Observations at unload, sale ring exit and load portions of the facility indicate that EMI does not exist at this livestock auction market within the spectrum of interest analyzed. A table of observations of equipment and materials can be found in Table 5.5.

J.C. Livestock Sales Company is located in Junction City, Kansas in the northeast region of the state. J.C. Livestock Sales Company marketed approximately 48,800 head of cattle in 2006. On June 24, 2006 EMI measurements were taken. During the initial free run period at the load/unload facility below trigger-level noises were noted that are not observed in a clean environment (Figure 5.10). The source of these noises was not determined; additionally, turning off the lights did not change the observations. While these noises were not significant enough to cause triggers (Figure 5.11) they are important to note as they might interfere to a nominal extent. At the exit of the sale ring no noises were observed and no triggers were received which allowed this area to be designated a clean environment. Observations of equipment and materials for both sites evaluated are listed in Table 5.6.

Sylvan Sale Commission, LLC is located in Sylvan Grove, Kansas in the north central region of the state. In 2006 Sylvan Sale Commission, LLC marketed approximately 23,600 head of cattle. EMI measurements were collected on July 17, 2006. EMI testing at unload, exit of the sale ring and load facilities of this livestock auction market indicate that the environment is clean or free from EMI in the spectrum evaluated. Observations of equipment and materials from each site at the auction market are noted in Table 5.7.

Clay Center Livestock Sales Company is located in Clay Center, Kansas in the north central region of the state; in 2006 they marketed approximately 26,700 head of cattle. EMI observations were conducted on June 27, 2006 at unload/load and exit of the sale ring locations. Within the spectrum of testing no interferences were observed indicating this livestock auction market has a clean environment. A list of equipment and building material observations is located in Table 5.8.

Atchison County Auction Company, Inc. in Atchison, Kansas and is located in the northeast region of the state. In 2006 approximately 13,600 head of cattle were marketed through this livestock auction market. Observations of EMI were taken on July 1, 2006. Measurements at unload, sale ring exit and load portions of the facility indicate that EMI does not exist at this livestock auction market within the spectrum of interest analyzed. Electrical, building material characteristics and equipment observations are noted in Table 5.9.

Hays Livestock Market Center, Inc., is located in Hays, Kansas in the north central region of the state. In 2006 this auction market marketed approximately 15,500 head of cattle. On July 5, 2006 observations of EMI were collected at unload, sale ring exit and load portions of the facility. The measurements indicate that EMI does not exist at this livestock auction market within the spectrum of interest analyzed. Table 5.10 lists observations of equipment and facility materials.

Farmers and Ranchers Livestock Commission Company, Inc. is located in Salina, Kansas in the north central region of the state. This is the largest livestock auction market in Kansas selling approximately 211,500 head of cattle in 2006. EMI measurements were made on July 13, 2006 at unload, exit of the sale ring and load areas of the facility. The measurements taken within the spectrum of interest indicate that there are no potential interferences and the environment is considered clean. A list of observations of materials and equipment at the auction market can be found in Table 5.11.

La Crosse Livestock Market, Inc. is located in La Crosse, Kansas in the south central region of the state. In 2006 approximately 51,700 head of cattle were marketed through this livestock auction market. Observations of EMI were made on July 14, 2006 at unload/load and exit of the sale ring locations. Measurements indicate that there are no potential interferences within our spectrum of interest. Therefore, this livestock auction market is recognized as a clean environment. Table 5.12 provides a list of materials and equipment noted at each location.

Pratt Livestock, Inc is located in Pratt, Kansas in the south central region of the state. In 2006 approximately 188,400 head of cattle were marketed through this livestock auction market. On July 20, 2006 EMI measurements were taken at unload, exit of the sale ring and load locations. The unload and load locations were found to be free of interference in the spectrum evaluated and recorded as clean environments.

However, at the exit of the sale ring two peaks were observed at 125.49 kHz, -105 dBm and 156.88 kHz, -107 dBm (Figure 5.12). In a three hour testing period these two peaks caused 26 triggers to be recorded. Triggers occurred as the SA antenna was moved from the primary location by door toward the penning station, computer monitor, electrical power hub, and fluorescent lights. In trying to determine the source of the noise/interference the antenna was moved around the area using the free run setting. The dBm level increased for each peak as the SA antenna was moved closer to the penning work station. A single source of noise could not be identified. Table 5.13 has a list of all equipment and materials in each location evaluated for EMI.

Farmers Livestock Commission Company, Inc. is located in Caldwell, Kansas in the south central region of the state. In 2006 they marketed approximately 4,700 head of cattle. Observations of EMI were taken on July 22, 2006. Observations at unload, exit of the sale ring and load locations in the facility indicate that EMI does not exist at this livestock auction market within the spectrum of interest analyzed. A table of observations of equipment and materials observed at each location can be found in Table 5.14.

Winfield Livestock Auction Company, Inc. of Winfield, Kansas is located in the southeast region of the state and in 2006 marketed approximately 38,200 head of cattle. Measurements of EMI were taken on July 26, 2006. Observations at unload/load and the exit of the sale ring locations indicate that EMI does not exist at this livestock auction market, within the spectrum of interest analyzed. A table of observations of equipment and materials can be found in Table 5.15.

Of the livestock auction markets evaluated in this study only one had a significant level of noise. As noted in the Holton barn, it is possible to find noises that could potentially interfere, but was only detected with the SA when the antenna was placed in very close proximity (6 inches) to the equipment creating the interference.

While, the presence of EMI does exist in livestock auction markets it is quite limited. Table 5.16 provides a summary of all livestock auction markets and the triggers collected at each. The configuration and design of the RFID equipment in the sale barn can have a more significant impact on the ability of the equipment to work than potential EMI.

Electromagnetic interference evaluation in 4 commercial feedlots throughout Kansas

Great Bend Feeding, Inc. is located in Great Bend, Kansas in the south central region of the state. Great Bend Feeding, Inc. has a once time capacity of approximately 27,000 head. The feedlot has one processing barn and one load/unload facility; both areas were evaluated for EMI on October 24, 2007. A handheld low-frequency RFID transceiver is used to record eID transponders. In the first two hours at the processing barn the two triggers received, indicating interference, occurred when the hydraulics were either turned on or off. During the third hour in the processing barn three triggers occurred and the source of this interference was not determined; triggers did not coincide with turning on/off of the hydraulic squeeze chute. The location of the SA antenna relative to the hydraulic squeeze chute can be noted in Figure 5.15.

While using the free run setting in the processing area potential interferences were noted as the SA antenna was introduced to an area with a refrigerator (medicine cabinet) illuminated by a fluorescent light. Figure 5.14 shows the observed interference when the SA antenna is approximately six inches from the refrigerator with the fluorescent light directly inside the door. With the exception of the noise produced by the refrigerator/fluorescent light the remainder of the area was clean, without interferences (Figure 5.13).

At the load/unload site one trigger occurred each hour and the source of this interference was not determined. On the free run setting no observations of potential interference were measured.

Table 5.17 lists equipment and materials observed at both locations. Table 21 provides a summary of triggers colleted at each location.

Knight Feed Yard is located in Lyons, Kansas in the south central region of the state. Knight Feed Yard has a one time capacity of approximately 16,000 head of cattle. EMI measurements were taken on October 26, 2007. There are two processing facilities and two unloading/loading facilities, EMI measurements were taken at all locations. The north processing and load/unload areas are within 20 feet of each other and were therefore tested simultaneously. A handheld low-frequency RFID transceiver is used for cattle with eID tags.

At the south processing facility one trigger was recorded when the hydraulic squeeze chute was turned off, no other interference was noted during processing. During a processing break the handheld RFID tag transceiver was intentionally activated causing three triggers. A computer station with an old style computer monitor, laptop and "Black Box" created a measurable noise when the SA antenna was introduced to the area on the free run setting (Figure 5.19 and 5.16).

No triggers or measurable noise interference was observed at the south load/unload facility indicating this environment is clean.

The north load/unload and processing site had a significant level of interference from an electrical light pole (Figure 5.17, 5.18 and 5.20). During the first hour of testing 55 triggers were obtained due to the SA antenna being moved into close proximity of the light pole. The second hour of testing resulted in no triggers suggesting that if the RFID equipment is further away from the light pole there should be less EMI to create a problem. However, if RFID equipment was to be used in near vicinity of the light pole EMI might create a problem for the effectiveness of the equipment.

Table 5.18 lists equipment and materials observed at both locations. Table 5.22 provides a summary of triggers collected a each location.

Ward Feed Yard, Inc. is located in Larned, Kansas in the south central region of the state. This feed yard has a one time capacity of approximately 30,000 head of cattle. EMI measurements were taken on October 31, 2007. Ward Feed Yard has one processing, load and unload facility. EMI measurements could not be collected at the loading facility due to a lack of a power supply and extreme weather conditions (dust/sand storm). A handheld low-frequency RFID transceiver is used to read those cattle with eID tags as necessary.

Three triggers were collected during the first hour at the processing barn (Figure 5.22); they were the result of the hydraulics being turned on/off and turning on a heater which was plugged into the same power supply as the SA. No triggers were collected during the second hour of testing. There was one low level peak observed during testing in the processing barn (Figure 5.21), 133.75 kHz, -115 dBm.

Observations at the unloading facility indicate that there is no interference and therefore can be noted as a clean environment.

Table 5.19 provides a list of observations of equipment and materials at the processing and unloading facilities. Table 5.23 provides a summary of triggers collected at each location.

Supreme Cattle Feeders, LLC is owned by Agri Beef Company. Located in Kismet, Kansas this feedlot is in the far southwest region of the state. Supreme Cattle Feeders has a one time capacity of approximately 70,000 head of cattle. There are two processing and unload/load facilities, at the south unload/load a stationary low-frequency RFID panel transceiver system is installed. At the north processing facility a handheld low-frequency RFID transceiver is used for those cattle entering and at the yard with eID transponders.

EMI observations were made on November 8, 2007 at the north processing and unload facilities and on November 9, 2007 at the south processing and load facilities. At the north processing facility all triggers recorded occurred due to activation of cattle prods being used in the vicinity (Figure 5.23a and 5.23b). Neither the free run nor State B setting showed interference when cattle prods were not being used (Figure 5.24), therefore the environment is free of EMI other than that generated by the activation of cattle prods. The source of triggers collected at the north unload is unknown (Figure 5.26), a free run observation of this area did not reveal any EMI (Figure 5.25). Two triggers were collected at the south processing facility due to turning on and then off the lights, no other triggers occurred and no EMI was observed during the free run. The south unload/load facility is also the location of the stationary low-frequency RFID transceiver system. At this location no EMI was observed, allowing this area to be determined a clean environment.

A table of observations of materials and equipment is listed for each location in Table 5.20. Also available, in Table 5.24, are observations of triggers at each location.

Throughout testing in the feedlots potential interferences can be observed at processing, load and unload locations. Generally, an observation of a potential interference occurred in the cattle processing barns, however electromagnetic interferences above -90 dBm were observed at the load/unload sites as well. Equipment is often the source of the potential interference. These included cattle prods, fluorescent lights and computer monitors. In three of the four feedlots where potential interference was observed the feedlots are currently using a handheld eID tag reading system. Supreme Feeders, LLC has a stationary eID panel reading system at their south load/unload site and no electromagnetic interferences were observed at that location.

Electromagnetic interference evaluation in 5 abattoirs throughout Kansas and Nebraska

National Beef Packing Co. of Dodge City is located in southwest Kansas. This abattoir was evaluated for EMI on July 2, 2007 and July 3, 2007. The RFID transceiver installed at the plant is used to read low-frequency transponders on cattle with eID.

Observations of surroundings on each harvest floor.

- All material is stainless steel and aluminum
- Lighting: stadium-style (mercury halite)
- Large stainless steel trough located directly in front of RFID transceiver and SA antenna
- RFID transceiver is positioned on harvest chain after both sides of the carcass are hung by the Achilles tendon where hides are being removed
- Electrical wiring to RFID transceiver is enclosed in a metal pipe that runs from the power source at the computer station along the trough to the transceiver

- SA antenna is approximately 0.61 m from the center of the RFID transceiver, at the same distance from the carcasses as the RFID transceiver
- Air powered saws on opposite side of carcasses
- Carcass chain moves continuously and only stops for problems
- Horn sounds throughout entire harvest area to signal start and stop of carcass chain
- Industrial fans
- Hot water at all stations
- Horn removal occurs ~3.66 to 4.57 m from RFID transceiver
- Computer station ~3.05 m above SA antenna
- RFID transceiver by Allflex

The interferences observed at Dodge City National Beef Packing Co. varied between -125 dBm to -110 dBm. The observance of specific peaks was not constant among all orientations of the antenna. Figures 5.27 – 5.31 and Table 5.25 provide data regarding trigger and free run data collection.

Upon completion of each run a set of free run observations was completed. The location of the SA antenna was varied, moved incrementally away from the original location used for all trigger testing. The three free runs in Figures 5.32, 5.33, and 5.34 provide an example of one set. This was completed at the end of all runs in all abattoirs.

Tyson Fresh Meats, Inc. of Emporia is located in southeast Kansas. This abattoir was evaluated for EMI on July 19, 2007 and July 20, 2007.

Observations of surroundings on each harvest floor.

- SA antenna was located between two stations, one for plasma collection container removal and one was not in use.
- Fluorescent and stadium-style lighting (mercury halite)
- Aluminum and stainless steel stands and equipment
- Plasma collection station had a robotic arm operated by a human for removal of the container, the container was put onto a chain and sent to another room
- Air, electric and hydraulic powered tools
- Hydraulic horn remover is ~1.83 m from SA antenna
- All stations provided hot water
- Carcass chain moved continuously except for problems
- Chain horn signal

Throughout the duration of testing the basal level interference fluctuated from -115 dBm to -130 dBm. While observations during the free run of 5 min may suggest that the environment is "clean" or has very little interference, data collected at this abattoir demonstrates that during an hour of testing there are numerous electromagnetic interferences that reach a threshold of -90 dBm. Figures 5.35 – 5.39 and Table 5.26 provide information regarding free run and trigger data collection.

Finney County Tyson Fresh Meats, Inc., of Holcomb is located in southwest Kansas. This abattoir was evaluated for EMI on July 24, 2007 and July 25, 2007.

Observations of surroundings on each harvest floor.

- SA antenna ~6.10 m away from SA
- SA antenna ~0.91 m from ear and horn removal station, in large open area

- SA antenna located after both sides of the carcass are hung by the Achilles tendon, hide removal occurring
- Carcass mouth washing station ~3.66 m form antenna
- Fluorescent and stadium-style lighting (mercury halite)
- Horn removal uses a hydraulic machine
- Air, electric and hydraulic powered equipment
- Stainless steel
- Carcass chain horn
- Carcass chain does not stop except for problems

The Tyson Fresh Meats, Inc., Finney County abattoir had very low basal level interference and for the most part the number of triggers observed each hour is reflective of this lower level. Also noteworthy is that every time more than a dozen triggers were observed a shift was just beginning when there would be a great deal of power cycling (turning on and off) of equipment at this time. Figures 5.40 – 5.44 and Table 5.27 present data collected during free run and trigger settings of the SA.

National Beef Packing Co. of Liberal is located in southwest Kansas. This abattoir was evaluated for EMI on August 13, 2007 and August 14, 2007.

Observations of surroundings on each harvest floor.

- SA antenna ~0.46 m from RFID transceiver
- RFID transceiver located after both sides of carcass have been hung by the Achilles tendon
- Halogen light ~1.07 m from SA antenna

- Stadium-style lighting (mercury halite)
- Electric and hydraulic powered equipment
- Chain horn signal
- Carcass chain runs continuously unless a problem occurs
- Industrial fans
- Hot water at all stations
- Computer station directly above RFID transceiver
- Numerous pipes with electrical wiring throughout
- RFID transceiver by Allflex

The abattoir has an RFID tag reading system installed. The interference observed in this abattoir varied throughout the duration of testing; basal level interference fluctuated from -125 dBm to -110 dBm. Additionally, the number of interferences observed on the trigger setting was not consistent throughout, no particular time nor orientation of the antenna demonstrated a pattern to the triggers. Figures 5.45– 5.50 and Table 5.28 provide data regarding free run and trigger collection results.

Cargill Meat Solutions of Schuyler is located in northeast Nebraska. EMI evaluation was conducted on October 19, 2007, only one day of testing was conducted as a significant amount of data was collected from the first day.

Observations of surroundings on each harvest floor.

- SA antenna located ~0.30 m from RFID transceiver and ~4.57 m below RFID carcass trolley reader

- RFID transceiver is located after both sides of the carcass have been hung by the Achilles tendon
- Computer station has 2 computer monitors connected to RFID transceiver and carcass trolley reader
- Digital display of RFID transceiver and trolley reader ~0.91 m from computer station and 3 feet from RFID transceiver
- Hydraulic and electric powered tools
- Fluorescent and stadium style lighting (mercury halite)
- Hot water at all stations
- Chain horn signal
- Carcass chain does not stop except for problems
- Constant, irregular squeaking noise in vicinity
- Large open area behind SA with washing stations
- Carcass steaming station ends directly above SA antenna
- Concrete floors, walls and ceiling
- Stainless steel steps, galvanized and aluminum pipes and tubing
- Ear removal station ~3.05 m from SA antenna
- RFID transceiver by Digital Angel

The Schuyler, NE Cargill Meat Solutions abattoir had a constant peak at 115 kHz at a signal strength of -88 dBm which caused the -90 dBm triggers to occur very rapidly in every orientation (Figure 5.51 – 5.55). Furthering evaluation of this site we used the State A setting at -70 dBm, to observe if interference reached that threshold. For each of the observation times noted in Table 5.29 a 15 min State A -70 dBm setting was used, no triggers were observed.

Therefore, we can conclude that all interferences were of signal strengths between -70 and -90 dBm.

Additionally, this abattoir has installed a Destron Fearing RFID panel transceiver. The SA antenna was located approximately 0.30 m away from the RFID panel. Abattoir employees indicated that the RFID panel transceiver system has performed well for them. Destron Fearing technicians also noted the presence of significant electromagnetic interferences at the time of transceiver system installation. Collectively, these observations indicated that properly installed RFID transceiver systems can perform satisfactorily in environments containing significant electromagnetic interferences.

Abattoir EMI Evaluation Conclusions

Interferences can be observed in all abattoirs; however, the radio frequency and signal strength vary with individual abattoirs. Observations of EMI within an abattoir do not necessarily have the same frequency and signal strength for the entire duration of testing.

Three of the five abattoirs have low-frequency ISO 11785 RFID transceivers installed. The Schuyler, NE Cargill Meat Solutions abattoir which had the greatest amount of EMI has a transceiver installed and noted that they were satisfied with its performance. Two other plants with transceivers installed have had problems obtaining consistent reads on transponders. Therefore it is difficult to speculate that a specific quantity of EMI will or will not impact transceiver performance. Further testing needs to be completed to determine the impact frequency and signal strength have on RFID equipment performance, especially in environments such as abattoirs.

Overall conclusions

The current level of testing identified those potential interferences that exist in a variety of environments. The scope of this project does not allow us to identify an exact correlation between dBm level and kHz level to the potential impact on communication function of RFID transponders and transceivers. Now that environments have been characterized in livestock auction markets, feedlots and cattle abattoirs, environmental interferences can be introduced that are known to exist in these production environments into a controlled laboratory setting and evaluate the impact of a known EMI on transponder and transceiver performance and read distance. The ability to introduce observed potential interferences into a known environment will provide a necessary link for complete understanding of EMI.

A subset of triggers from each livestock auction market, feedlot and abattoir was evaluated. For each hour of the trigger setting up to five triggers were evaluated. The appendix provides a list of each trigger evaluated, the dBm and kHz level for each peak that contributed to the trigger is recorded. The only location with a pattern or consistency to the triggers recorded was at Cargill Meat Solutions in Schuyler, Nebraska.

Implications

EMI existed in all types of cattle production settings evaluated to some degree. The extent of interference and duration vary depending on many factors. At this point some specific sources of interference can be identified however many questions remain unanswered. Most importantly, given that interferences do exist, there is a need to further identify to what extent different signal strengths and frequencies have on low-frequency RFID equipment performance.

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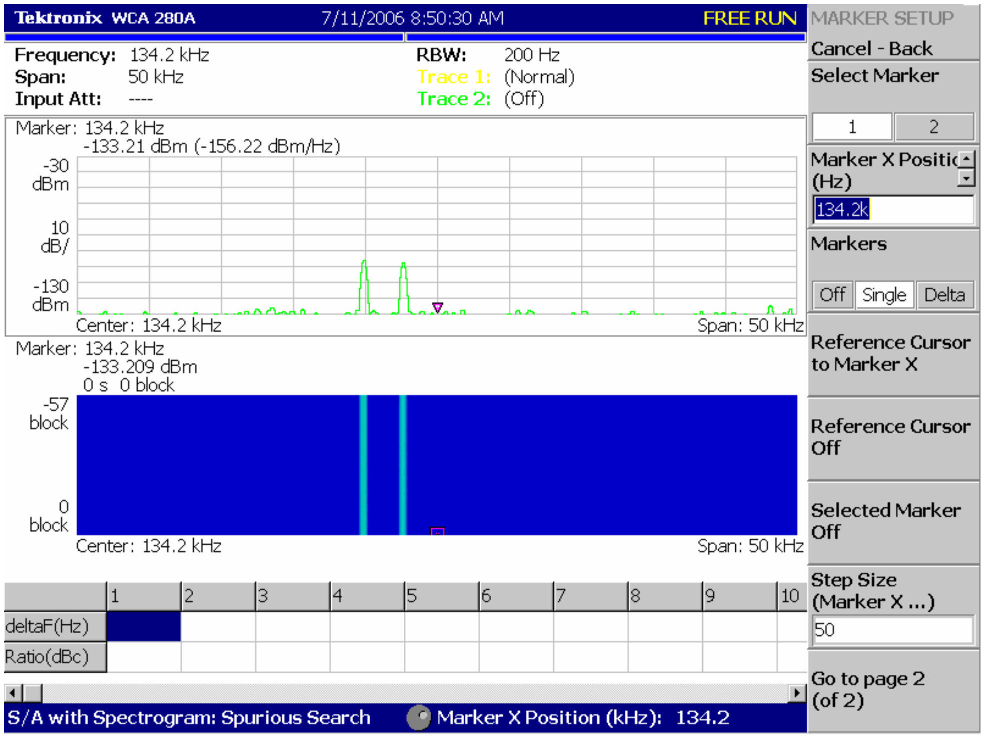
Figure 5.1 Free run, clean environment as observed at the Beef Stocker Unit



The two peaks in this figure are a product of the SA; they do not change when the basal-level interference changes although they can be masked by increased basal-level interference. The two peaks will not change in any environment.

Figure 5.2 Graphic depicting orientations of the antenna in relation to flow of cattle along the chain in the harvesting facility. Please note that the antenna does not move down the chain, it remains on the stand in a stationary position, the antenna is rotated on the stand.

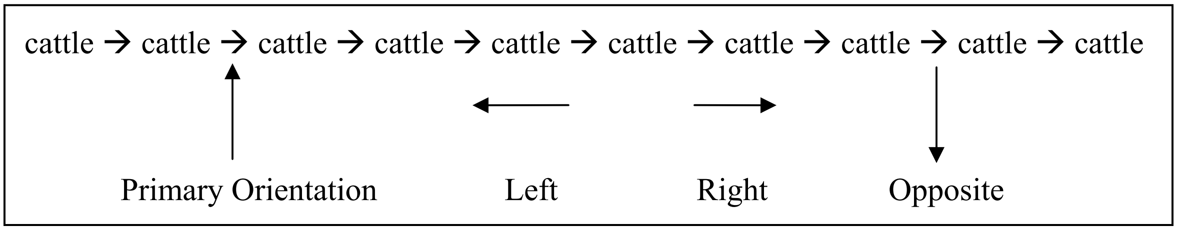


Table 5.1 Impact of lighting on read distance of five different transponders.

Transponder Brand	Lights On (cm)	Lights Off (cm)	Difference (cm)	Percent Improvement
Destron 12 chip	36.83	90.17	53.34	59%
Allflex HDX	39.37	139.7	100.33	72%
Allflex FDX-B	15.24	76.2	60.96	80%
Destron 15 chip	34.29	87.63	53.34	61%
Y-Tex	0	63.5	63.5	100%

Figure 5.3 Measurement of EMI in modular with lights turned on. The highest peak is at 132 kHz with a level of -97 dBm.

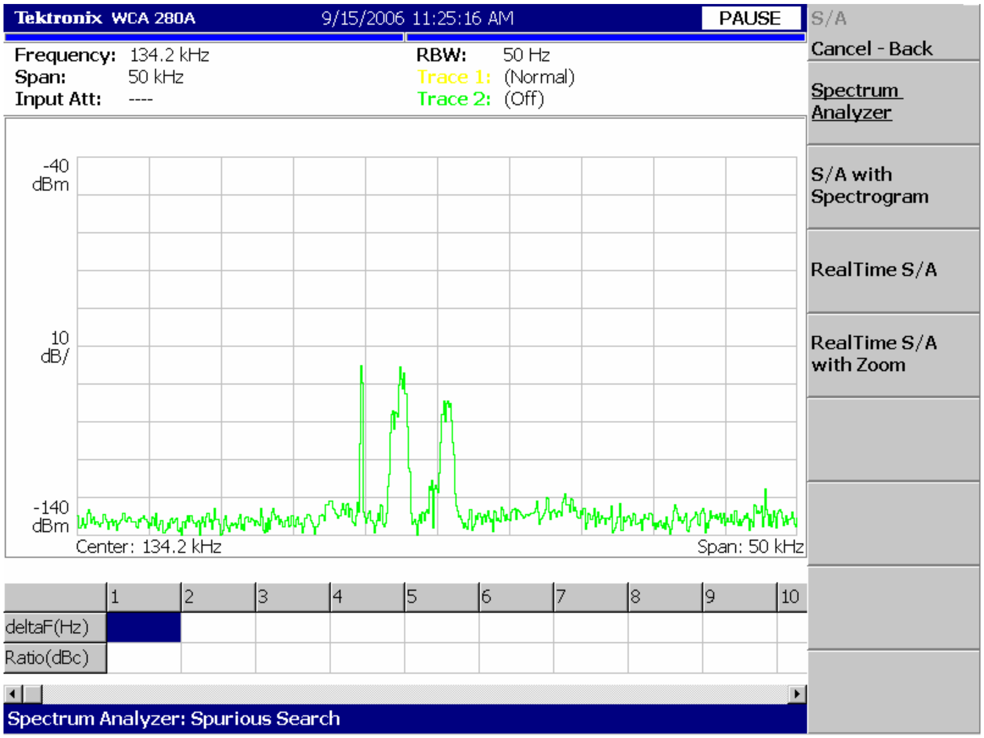


Figure 5.4 Measurement of EMI in the modular with lights turned off. The environment is evaluated to be clean, free of EMI.

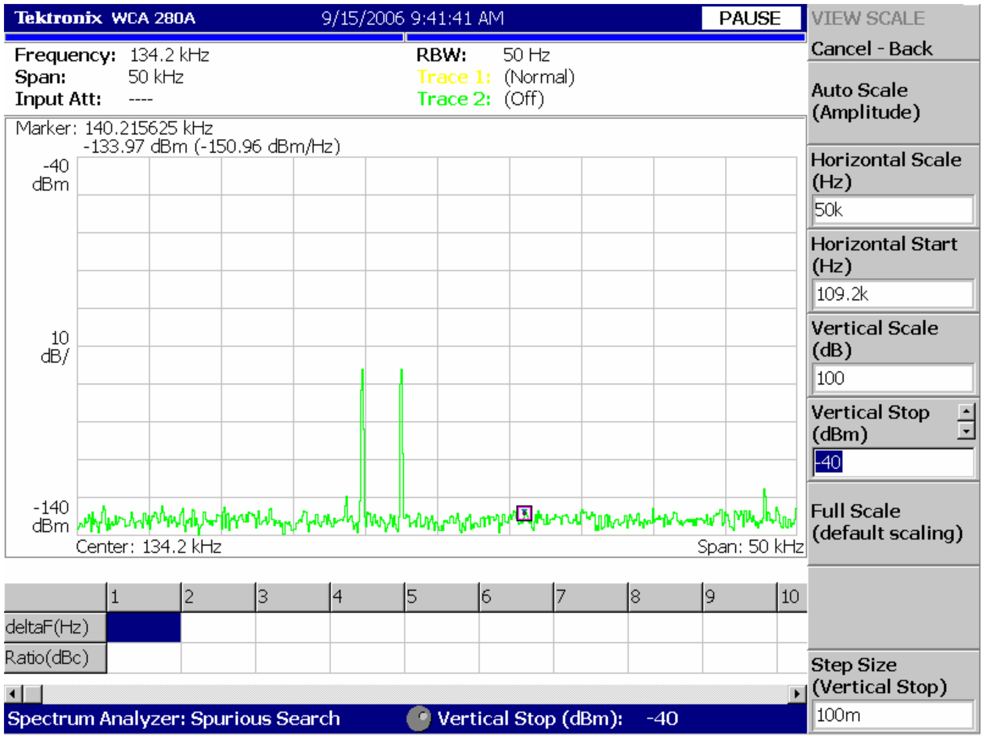


Figure 5.5 Measurement of EMI in modular with new ballasts, lights on. The environment is evaluated as clean, free of EMI. Any noises are below -125 dBm.

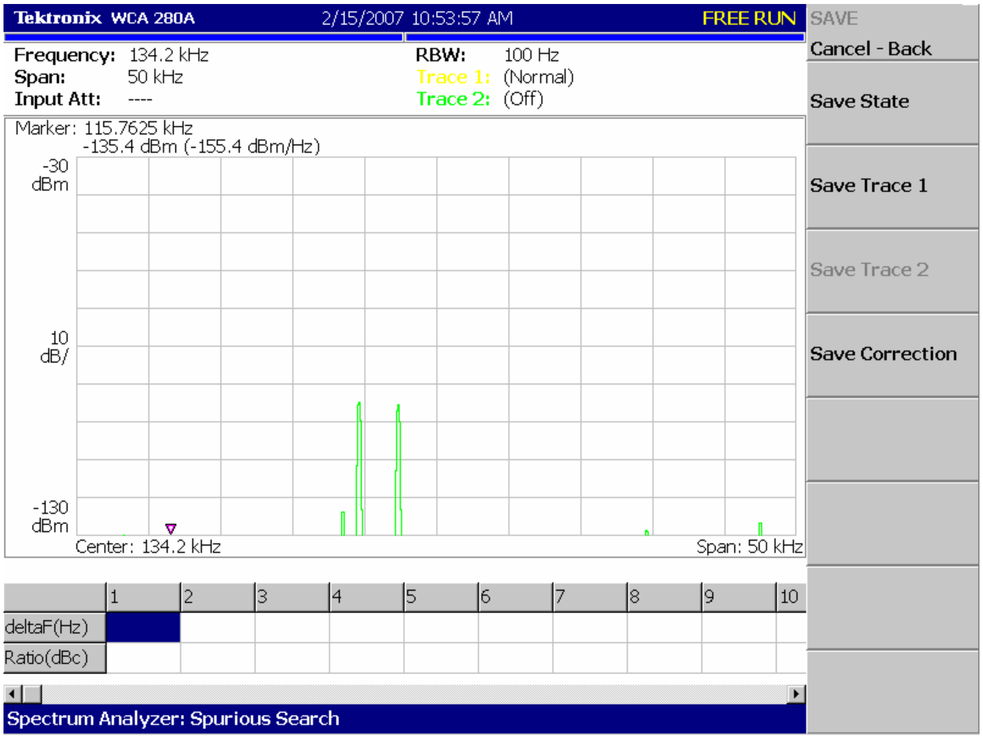


Table 5.2 Rezac Livestock Commission Company, Inc., Observations at each location.

UNLOAD	SALE RING EXIT	LOAD
Yard lights	Power box, electrical light switches	Metal pipe for fences, cement on ground
Metal pipe for pen fences	Metal pipe and 2x6 wood for pen fences	Power lines
Incandescent lights	Auction block ~2.7 m from SA antenna	Cattle prods, cattle prods
Power lines	Tin covered building, cement floor, steel beams, conduit pipe	TV antenna
14 gas pickups	Semi unload/load ~18.3 m away from SA antenna	Fluorescent lighting
15 diesel pickups	Air mail tubes	2 gas pickups
8 semis	Incandescent and fluorescent lighting	1 diesel pickup
	Digital pen number display	4 semis
	Hydraulic sale ring exit gate	PA loudspeaker
	PA loud speaker for penning, 2-way radios	

Table 5.3 Ft. Scott Livestock Market, Inc., Observations of each location.

UNLOAD	SALE RING EXIT	LOAD
Yard lights	Circuit breaker, electrical wiring throughout	Metal pipe for fences, cement on ground, tin roof, conduit pipe
Metal pipe for pen fences	Metal pipe for pen fences	Electrical wiring
Incandescent lights	Auction block ~1.5 m from SA antenna	Yard lights
Covered unloading area, wooden A-frame	Tin covered building, dirt floor, steel beams, conduit pipe	Incandescent lighting
Power lines	Welding equipment (off)	Light pole with power lines
	Misting system for pens	Circuit breaker
	Incandescent and fluorescent lighting	
	Industrial size fan	
	Computer for penning	
	PA loud speaker for penning	

Table 5.4 Holton Livestock Exchange, Inc., Observations at each location.

UNLOAD/LOAD	SALE RING EXIT
Metal, wooden and pipe fences with concrete floors	Metal pipe and wood for pen fences and gates
Electrical wiring	Auction block ~0.3 m from SA antenna
Incandescent and halogen lights	Tin covered building, cement floor, steel beams
2-way radios and intercom system	TV monitor/computer screen
Power lines	Incandescent lighting
Circuit breaker	Auction block: fluorescent lights
Covered by tin roof	PA loud speaker for penning, 2-way radios
TV, telephone and radio antennas	

Figure 5.6 Holton Livestock Exchange, Inc., Free run, antenna 0.15 m from TV monitor

4 significant peaks (left to right):
157.33 kHz @ -74 dBm
141.62 kHz @ -73 dBm
125.91 kHz @ -83 dBm
110.06 kHz @ -71 dBm

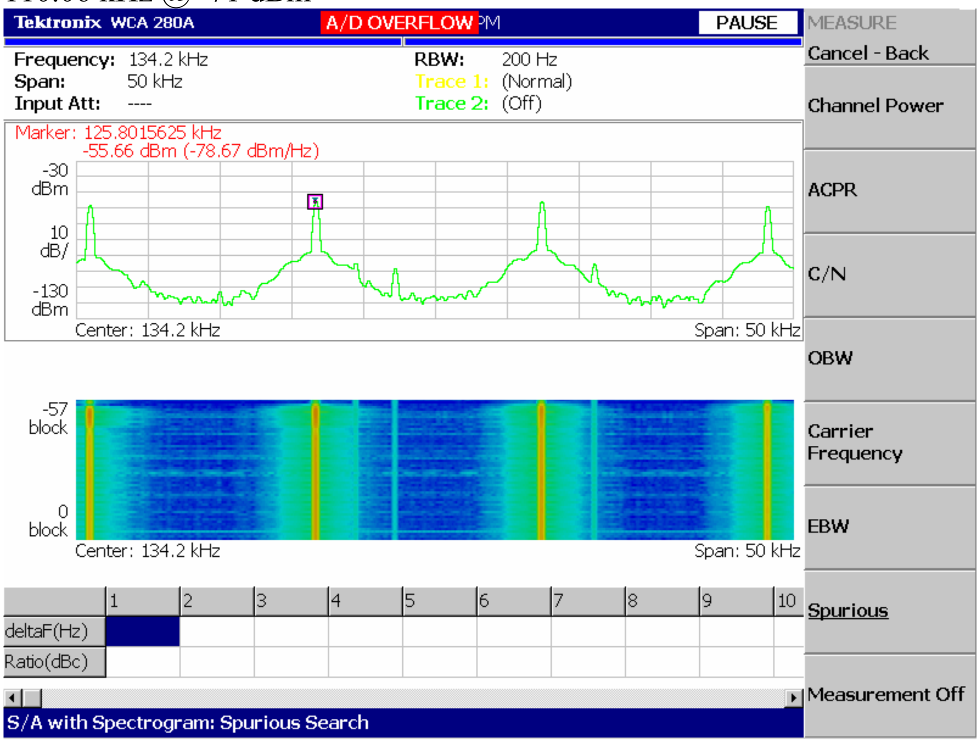


Figure 5.7 Holton Livestock Exchange, Inc., 2 triggers on -70dBm trigger setting

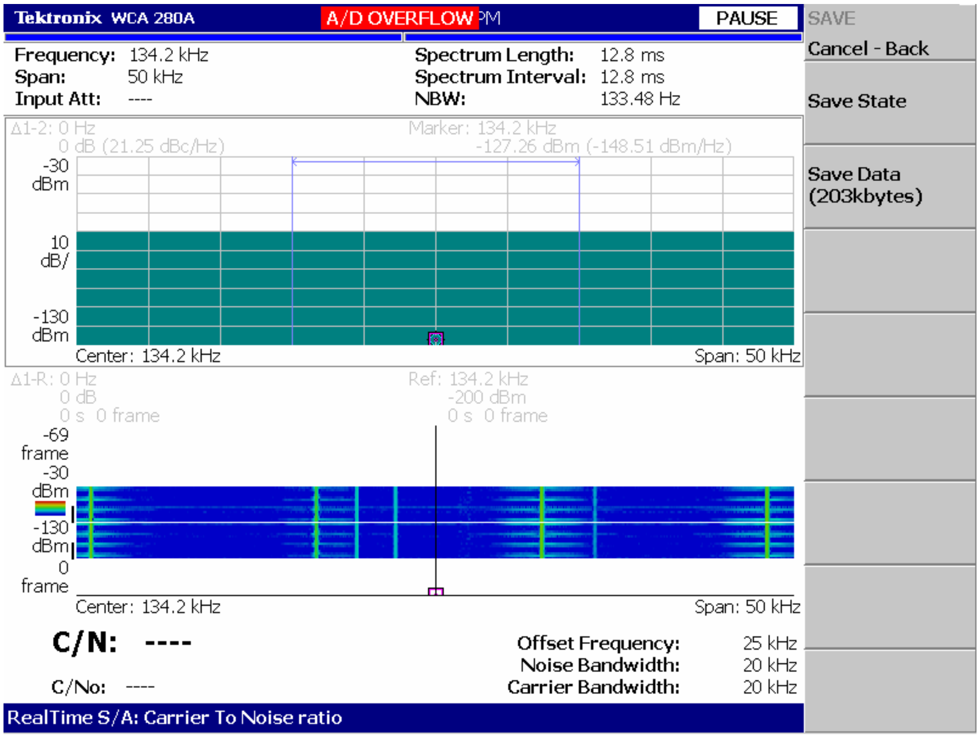


Figure 5.8 Holton Livestock Exchange, Inc., -70dBm trigger setting. SA antenna in primary location on stand. No triggers received.

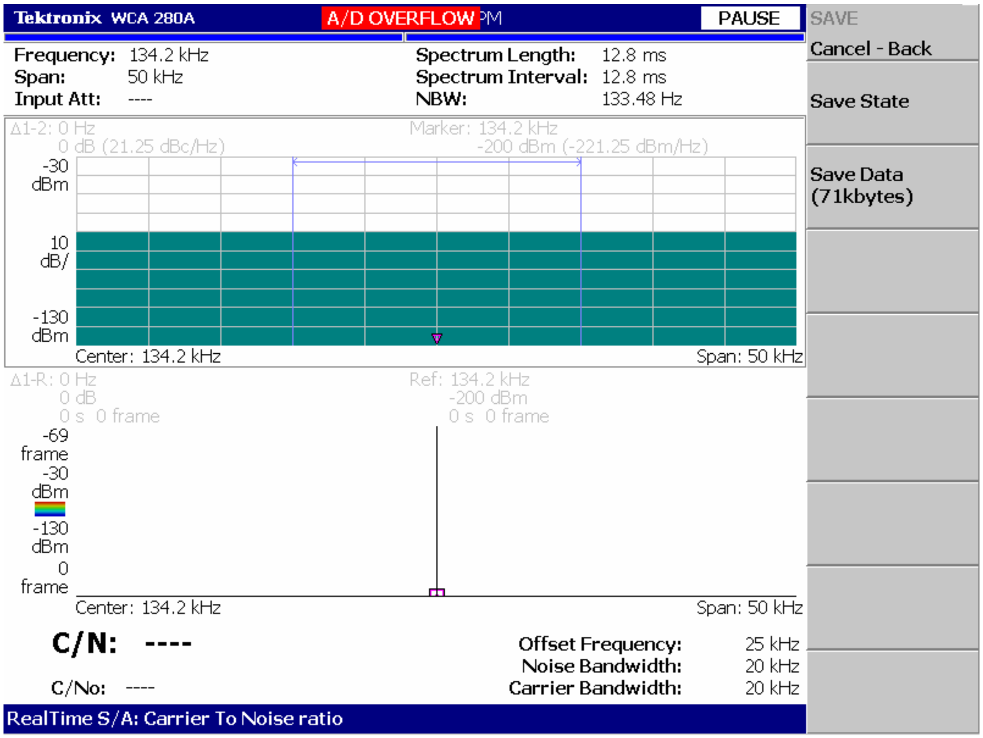


Figure 5.9 Holton Livestock Exchange, Inc., Note TV monitor – SA antenna within 0.15 m caused trigger.

Table 5.5 Manhattan Commission Company, Observations at each location.

UNLOAD	SALE RING EXIT	LOAD
Yard lights	Electrical wiring, circuit breakers	Metal pipe for fences, cement on ground
Metal pen fences, tin roof, cement floors	Metal pipe and sheets for pen fences	Power lines
Mercury halite lights	Auction block ~0.3 m from SA antenna	Incandescent lighting
Electrical wiring, power lines and light poles	Tin covered building, cement floor, steel beams, conduit pipe	Shack: wood with tin roof, telephone, microwave, heating unit, electrical wires
Surveillance camera, TV, VCR/DVD player in office	Power lines	Gas pipeline for heater
SA antenna ~1.8 m from office	Industrial fan	PA loudspeaker
Power transformers	Fluorescent, incandescent and mercury halide lighting	
Satellite dish	Hydraulic sale ring entry gate	
	PA loud speaker for penning	

Table 5.6 J.C. Livestock Sales Company, Observations at each location.

UNLOAD/LOAD	SALE RING EXIT
Yard lights	Metal pipe for pen fences
Metal pipe and wood for pen fences	Auction block ~0.6 m from SA antenna
Power lines and transformers	Tin covered building, wood supports
5 gas pickups	Circuit breaker
6 diesel pickups	Incandescent lighting
2 semis	Fluorescent lighting on auction block
Railroad tracks ~45.7 m away	Industrial fan
Vet shack ~22.86 m away	PA loud speaker for penning

Figure 5.10 J.C. Livestock Sales Company, Free run at unload/load, unusual peaks

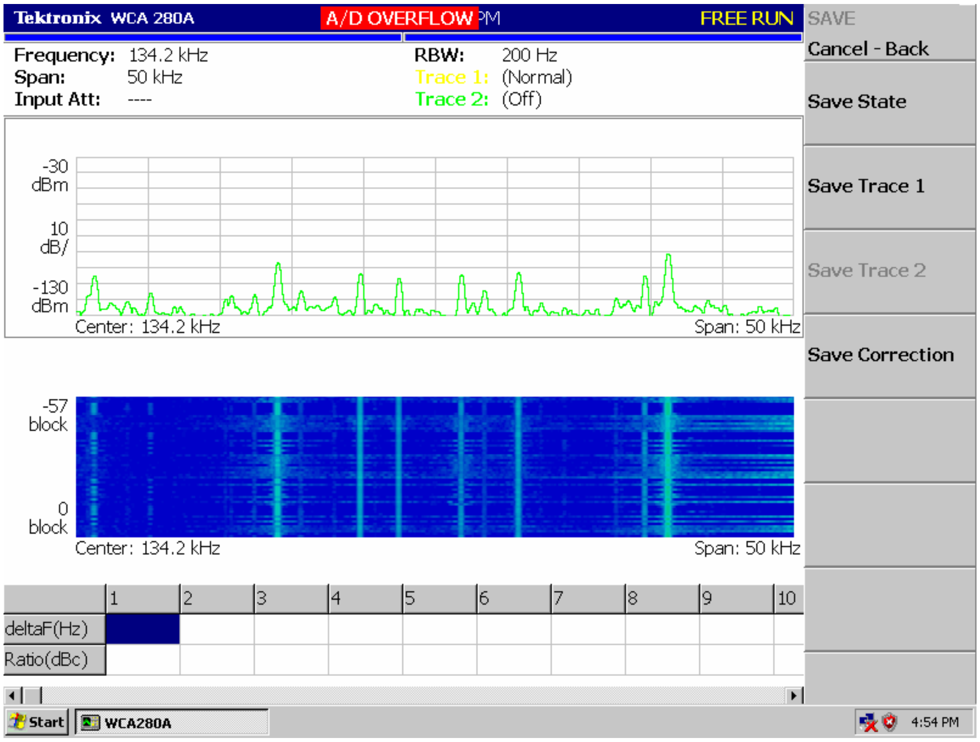


Figure 5.11 J.C. Livestock Sales Company, -70dBm trigger setting – No triggers received

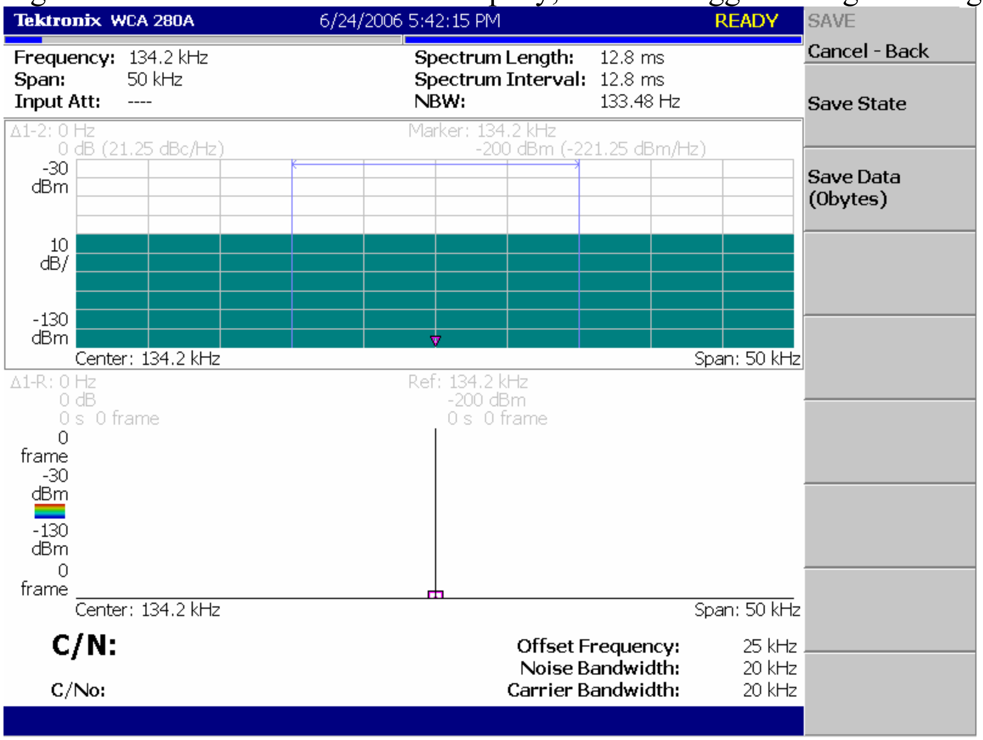


Table 5.7 Sylvan Sale Commission, LLC, Observations of each location.

UNLOAD	SALE RING EXIT	LOAD
Yard lights	Metal pipe for pen fences	Metal and chicken wire for fences, cement on ground
Metal pipe for pen fences	Auction block ~2.74 m from SA antenna	Power lines
Power lines and transformers	Tin covered building, cement floor and walls (½ way up)	Yard lights
Shack: tin and wood	3 industrial fans	Closest building ~27.4 m away
	Electrical wiring, not exposed	
	Incandescent and fluorescent lighting	
	PA loud speaker and computer for penning	

Table 5.8 Clay Center Livestock Sales Company, Observations at each location.

UNLOAD/LOAD	SALE RING EXIT
Yard lights	Metal pipe for pen fences
Metal pipe for pen fences, concrete floors	Auction block ~1.8 m from SA antenna
Halogen lights	Tin covered building, cement floor, steel beams, conduit pipe
Power lines	Garage doors on one side
Skid loader	Breaker box
Loudspeaker	Incandescent lighting
	Auction block: fluorescent lighting
	PA loud speaker for penning

Table 5.9 Atchison County Auction Company, Inc., Observations in each location.

UNLOAD	SALE RING EXIT	LOAD
Building: cinder block, wood and tin roof	Auction block ~1.2 m away	Yard lights
Telephone and battery operated clock in building	Pens: wood with metal gates on concrete, steel beams, tin roof	Power lines
Meter/power pole	Incandescent lighting	Metal pipe pens on concrete
Power lines	PA system for penning	Electrical breaker box
Metal pipe, concrete, tin roof	Auction block: cinder block and tin	
Satellite dish	Hydraulic cattle chute	
Incandescent and fluorescent lighting	Industrial fan	

Table 5.10 Hays Livestock Market Center, Inc., Observations in each location.

UNLOAD	SALE RING EXIT	LOAD
Yard lights	Concrete building, metal pipe fences, tin roof	Yard lights
Metal pipe on concrete	Incandescent lights	Metal pipe fences
Cinder block building with tin roof	Auction block ~0.3 m away, fluorescent lighting	5 gas pickups
10 gas pickups	Breaker box	3 diesel pickups
1 diesel pickup	PA system for penning	
	Electrical wires in pipe throughout	
	Industrial fan	

Table 5.11 Farmers and Ranchers Livestock Commission Company, Inc., Observations in each location.

UNLOAD	SALE RING EXIT	LOAD
Yard lights	Auction block ~1.8 m away	Metal pipe and wood for fences on concrete
Metal pipe for fences, wood on gates, on concrete	Auction block: brick with tin and wood roof, concrete floors	Power lines
Incandescent and halogen lights	PA system for penning	Yard lights
Power lines	Pens: metal and wood on dirt	Power lines and electrical wiring
24 gas pickups	Incandescent, fluorescent and mercury halite lighting	Air conditioner and TV in office, cinder block, tin covered
17 diesel pickups	Building: metal beams, tin roof	3 gas pickups
5 semis	Two-way radios	3 diesel pickup
2 ground load trailers	Industrial fans	7 semis
		Rail road ~45.72 m away

Table 5.12 La Crosse Livestock Market, Inc., Observations in each location.

UNLOAD/LOAD	SALE RING EXIT
Yard lights	Fluorescent lights
Metal pipe for fences on concrete	Computer system ~1.5 m away on auction block
Incandescent lights in office	Auction block ~1.5 m away
Power lines	Fans and air conditioning
Office: cinder block with tin roof	Video cameras for auction
Incandescent and halogen lighting	Digital display screen
	Metal pipe fencing
	PA system for auctioneer

Table 5.13 Pratt Livestock, Inc., Observations in each location.

UNLOAD	SALE RING EXIT	LOAD
Metal pipe pens on concrete	PA system from auction block	Office: cinder block, tin roof
Office: tin and wood, incandescent and fluorescent lights	Auction block ~3.0 m away	Metal pipe pens on concrete, wood walkways
Power lines	PA system for penning	Heat lamp
Yard lights	Fluorescent and halogen lights	Yard lights
Feed mill ~27.4 m away	Computer monitor, telephone, microphone, toggle switch	Power lines
TV satellite dish	Hydraulic gate	
Circuit breaker	Fan, heating unit	
	Electrical box	
	Fluorescent lights in alley	
	Wood frame room, tin covered	

Figure 5.12 Pratt Livestock Inc., Triggers observed, each greater than -70 dBm, at the sale ring exit. 26 total triggers were observed in a 3 hour period.

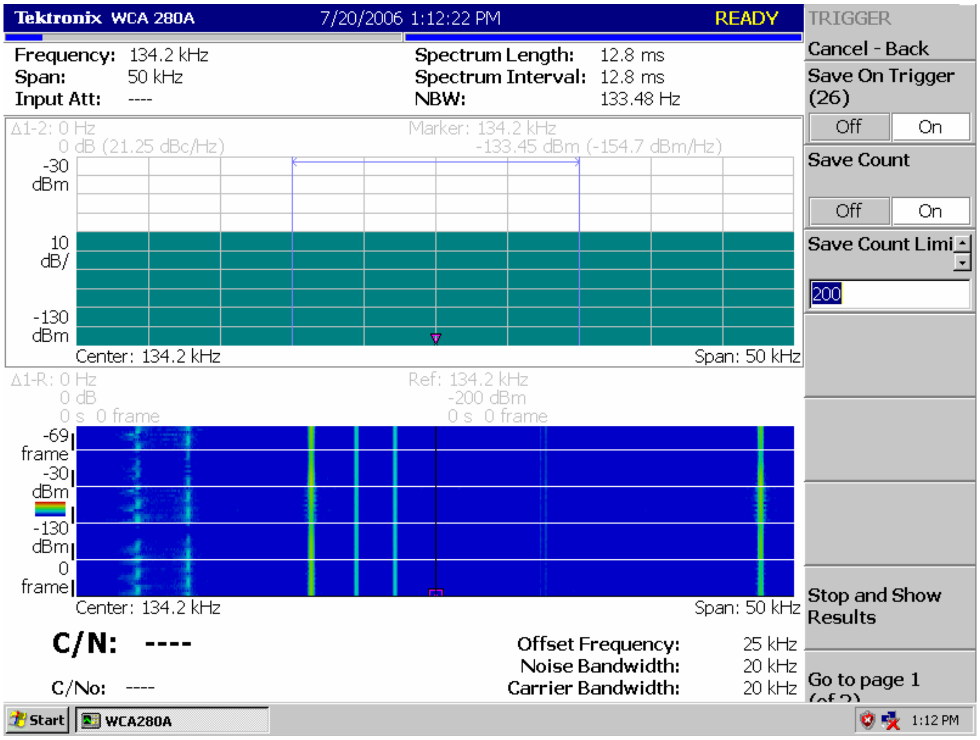


Table 5.14 Farmers Livestock Commission Company, Inc., Observations in each location.

UNLOAD/LOAD	SALE RING EXIT
Yard lights	PA system for penning
Metal pipe for fences	Metal pipe fencing
Incandescent lights	Scale: wood, tin covered
Power lines	Fluorescent lights
Power Transformer	~2.74 m from auction block
	Electrical wiring throughout
	Vet station ~9.1 m away
	2-way radios for penning

Table 5.15 Winfield Livestock Auction Company, Inc., Observations in each location.

UNLOAD/LOAD	SALE RING EXIT
Yard lights	Metal and concrete with tin roof
Power lines	Hydraulic ring entrance gate
Metal pipe for pens	Halogen and yard lights
PA system for penning	2-way radio for penning
Office: incandescent lights, AM/FM radio, telephone, heating unit, box fan	Auction block ~1.5 m away

Table 5.16 Observations of trigger occurrence summarized in all 14 auction markets

	UNLOAD		RING EXIT		LOAD	
Auction Market Location	Free run	-70dBm Triggers/hr	Free run	-70dBm Triggers/hr	Free run	-70dBm Triggers/hr
St. Mary's	clean	0/2	clean	0/3	clean	0/2
Ft. Scott	clean	0/2	clean	0/3	clean	0/2
Holton	clean	0/1.5	TV monitor	0/2	same as unload	
Manhattan	clean	0/2	clean	0/3	clean	0/2
Junction City	low-level peaks	0/2	clean	0/3	same as unload	
Sylvan Grove	clean	0/2	clean	0/3	clean	0/0
Clay Center	clean	0/2	clean	0/2.5	same as unload	
Atchison	clean	0/2	clean	0/1.5	clean	0/1.25
Hays	clean	0/1.25	clean	0/2	clean	0/2
Salina	clean	0/2	clean	0/3	clean	0/2
La Crosse	clean	0/2	clean	0/3.25	same as unload	
Pratt	clean	0/1.75	noise	26/3	clean	0/2
Caldwell	clean	0/2	clean	0/1	clean	0/2
Winfield	clean	0/2	clean	0/3	same as unload	

Table 5.17 Great Bend Feeding, Inc., Observations of surroundings at each location

PROCESSING	LOAD/UNLOAD
Fluorescent lighting	Metal alley with dirt leading to chutes
Medicine refrigerator with fluorescent lights	Wooden chute for tall deck trucks
Concrete and plywood building, tin roof	Primary chute: wood with metal supports and cement floors
Heating elements in 2 corners	5 yard lights along alley
One main breaker box	Semis drove by to feed mill
Industrial fan	Feed mill ~91.4 m away
Metal alley way on concrete	
Wall separating chute from tub area	

Figure 5.13 Great Bend Feeding, Inc., Free run observation of processing area, antenna ~2.4 m from hydraulic chute

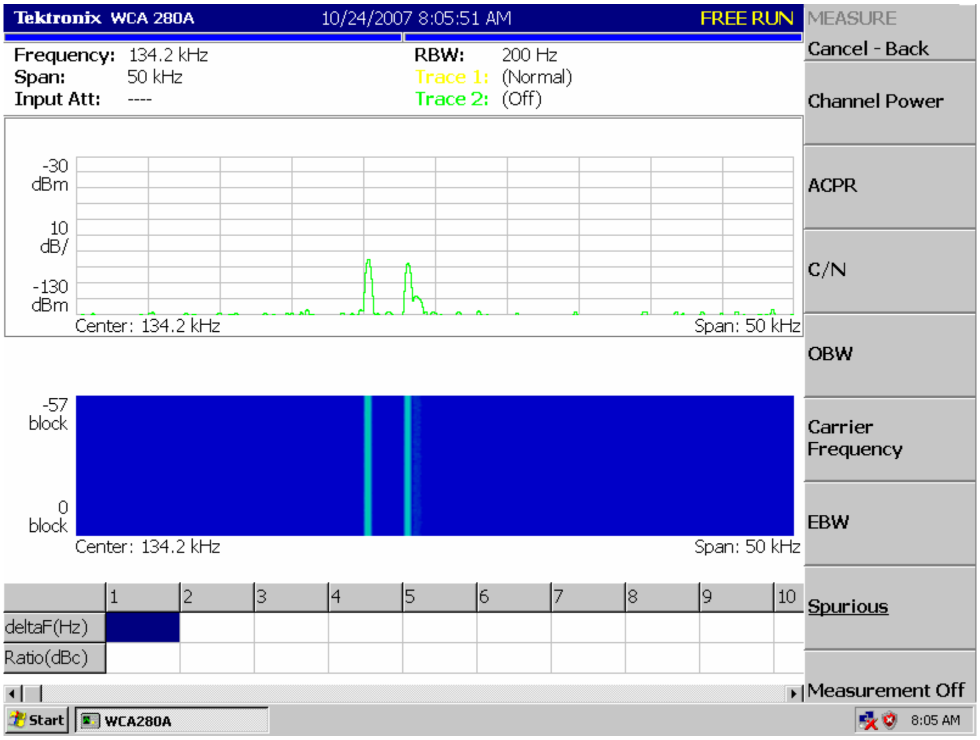


Figure 5.14 Great Bend Feeding, Inc., Free run observation of fluorescent light inside medicine cabinet.

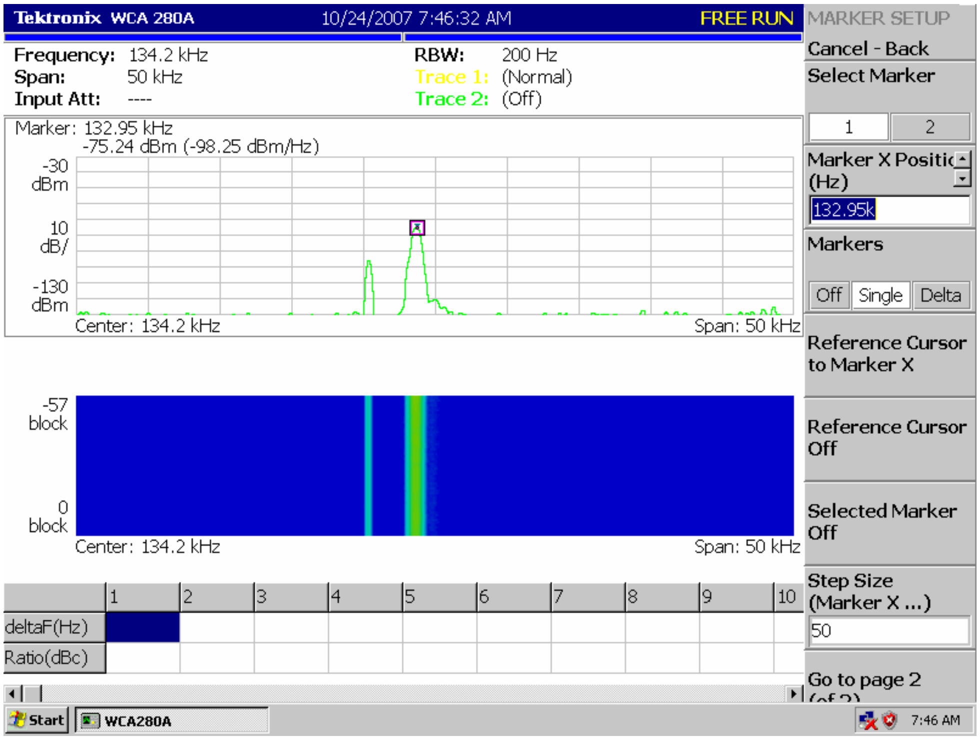


Figure 5.15 Great Bend Feeding, Inc., SA antenna in foreground with hydraulic cattle chute in background.

Table 5.18 Knight Feed Yard, Observations of surroundings at each location

SOUTH PROCESSING	SOUTH LOAD/UNLOAD	NORTH LOAD/UNLOAD
Hydraulic chute	Wall of processing shed is one side of alley	Light pole with electricity, potential interference
Stadium-style lighting	Alley: sheet metal, pipe, concrete floor	Metal alley on concrete
Heating elements	Yard lights	Wireless antenna on top of processing barn
Computer station with old-style monitor, laptop and “Black Box”		Yard lights
Small refrigerator		
Metal alley over grated floors		
Industrial fan		
Water supply		
Tin roof and siding, cement floors		

Figure 5.16 Knight Feed Yard, Free run observation of computer monitor and "Black Box" in south processing area

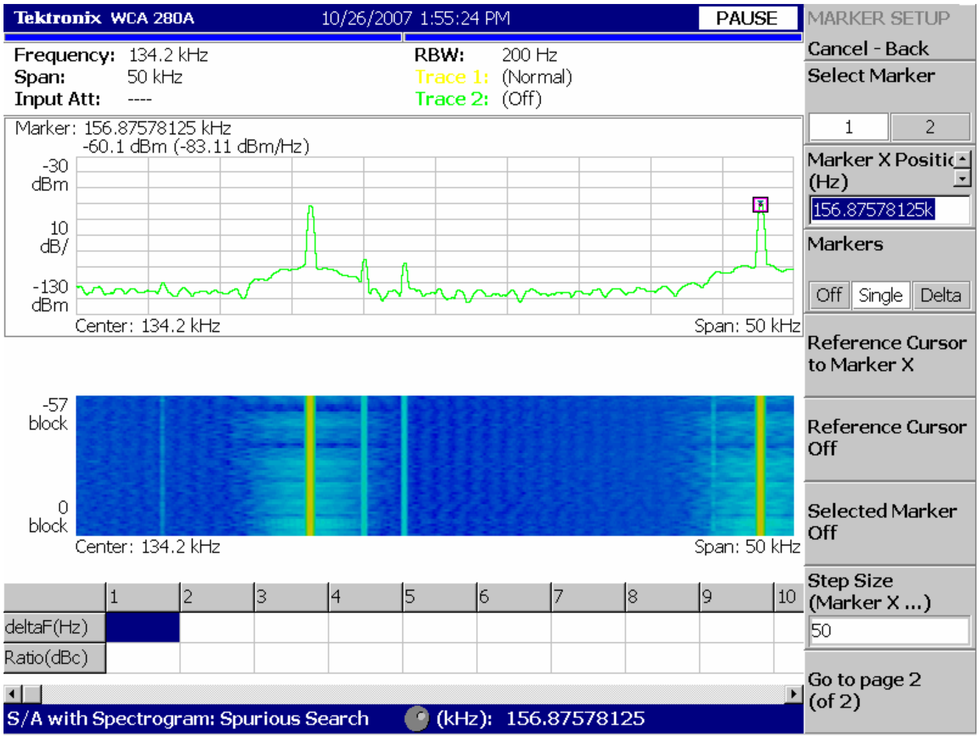


Figure 5.17 Knight Feed Yard, Free run observation of north load/unload – peak at 125.5 kHz, -109 dBm

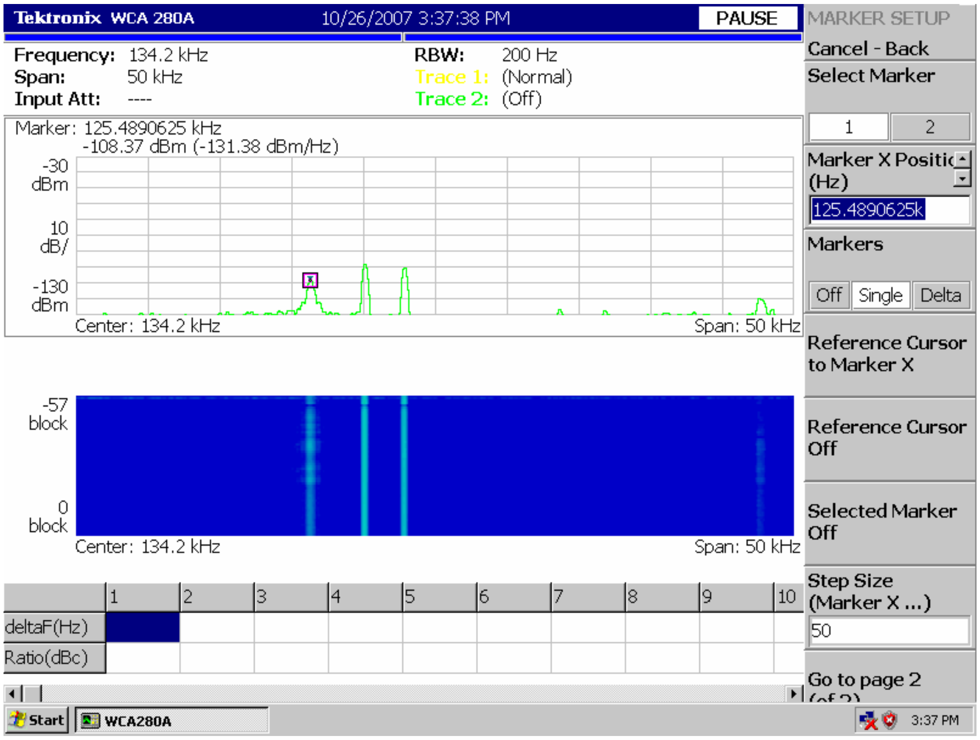


Figure 5.18 Knight Feed Yard, Free run observation of north load/unload, peak is from light pole ~0.6 m away

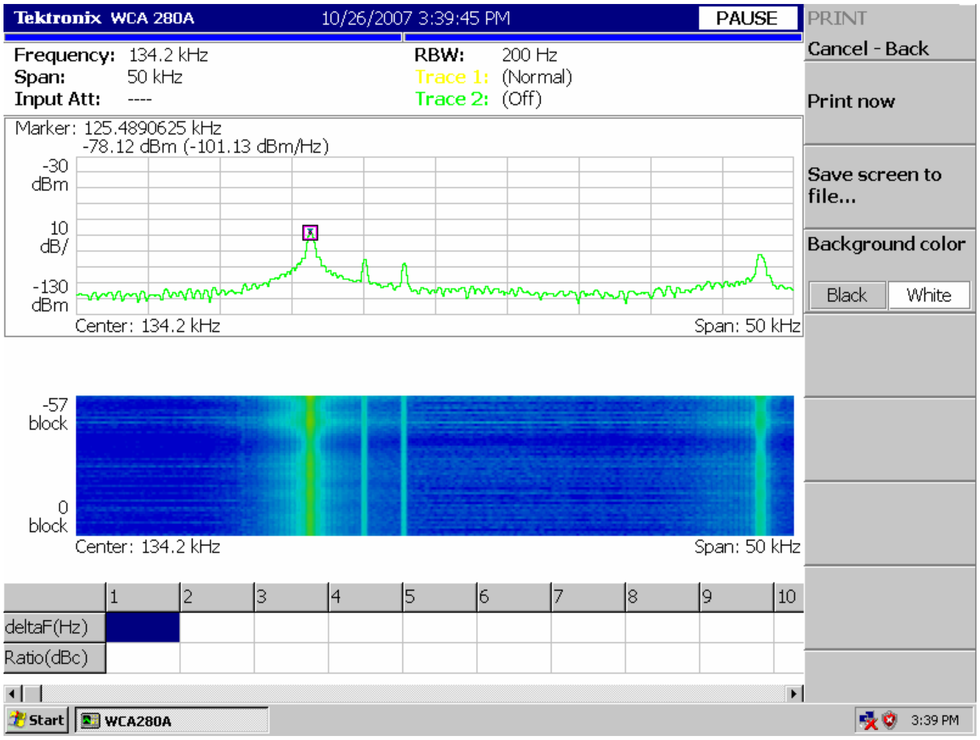


Figure 5.19 Knight Feed Yard, Picture of computer and black box, noted in Figure 5.16, cause of potential interference

Figure 5.20 Knight Feed Yard, Light pole at south load/unload cause of triggers and interference noted it Figure 5.18.

Table 5.19 Ward Feed Yard, Inc., Observations of surroundings at each location

PROCESSING	UNLOADING
Silencer hydraulic chute	Metal unloading chute on cement
Metal alley on grated floors	Yard lights
Tub and chute within processing barn	Power lines
Halogen and fluorescent lights	Feed mill ~91.4 m away
Air compressor, heating element	Feed trucks and pickups
Medicine refrigerator with light	No good pinch point at unloading, except chute
Can read eID tags, not today	
Tin roof and siding, cement floors	

Figure 5.21 Ward Feed Yard, Inc., Free run observation of processing barn, peak at 133.75 kHz, -115 dBm.

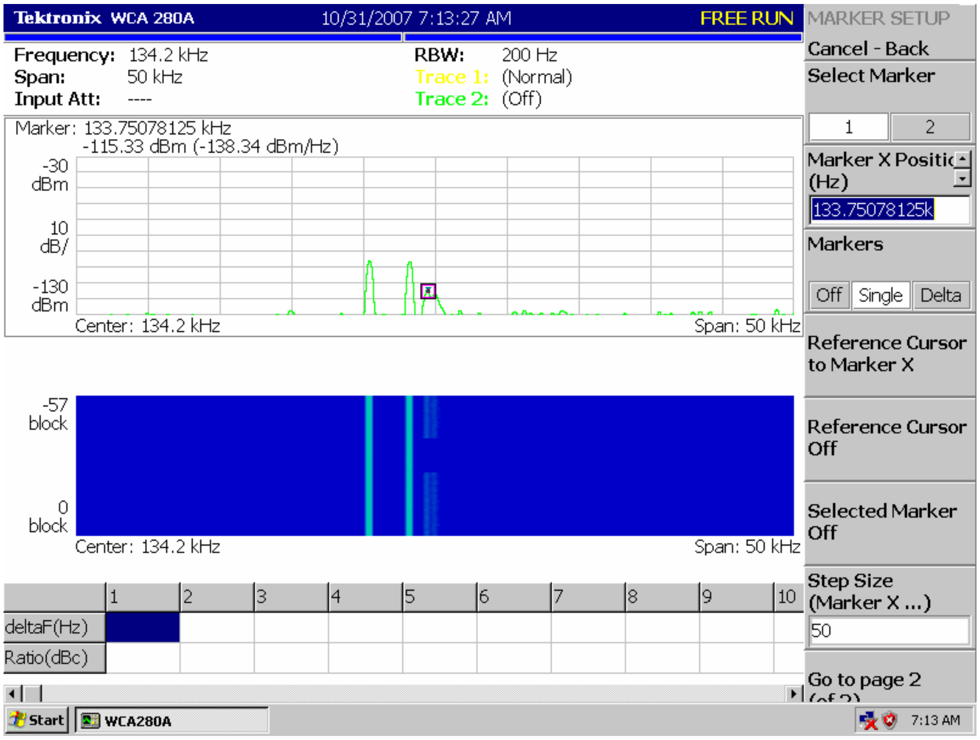
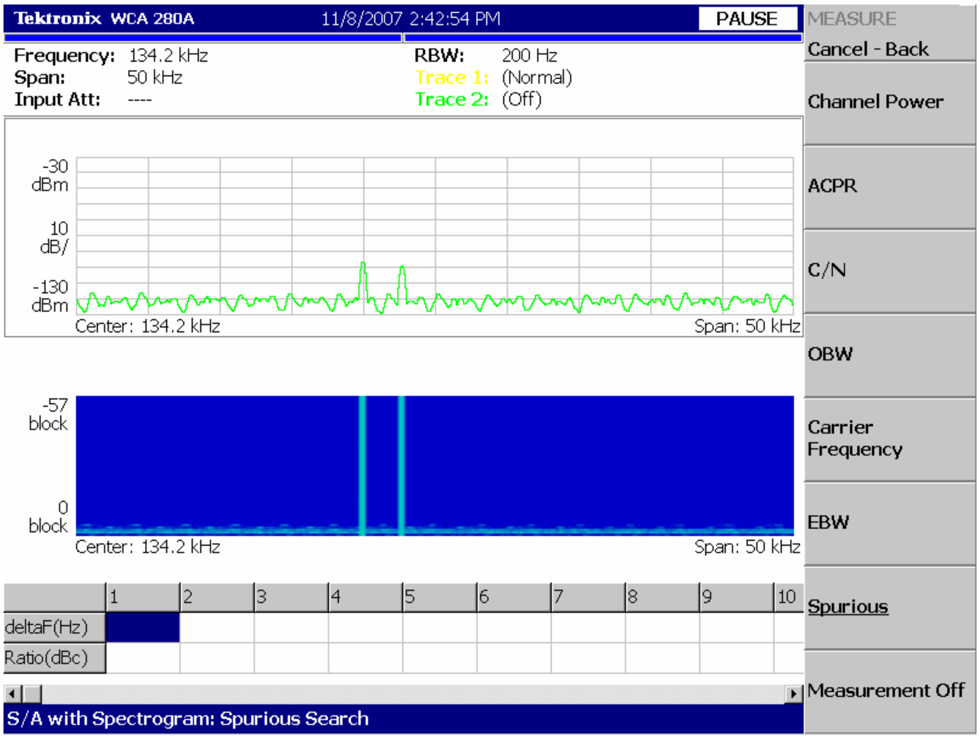


Figure 5.22 Ward Feed Yard, Inc., Spectrum Analyzer in foreground with SA antenna and hydraulic chute in background.

Table 5.20 Supreme Cattle Feeders, LLC, Observations of surroundings at each location

NORTH PROCESSING	NORTH LOAD/UNLOAD	SOUTH PROCESSING	SOUTH LOAD/UNLOAD
Hydraulic chute	Large halogen yard lights	Hydraulic chute	eID tag reading alley – transceivers off, plastic with metal supports on concrete
Incandescent, stadium-style lights	Metal Pipe fencing	Metal processing alley over grated floors	
Cattle prods ~4.6 m away at greatest distance from antenna (cause of triggers)	Concrete on ground	Water and electricity throughout	Metal fencing
Industrial fans	SA antenna ~45.72 m from processing barn	Fluorescent lighting	Electricity to eID transceivers from scale house
Metal processing alley over grated floors	Power lines	Space heater hanging from ceiling	Yard lights
Tin roof and siding, cinder block (one side), cement floors		Tin roof and siding, cinder blocks (2 sides), cement floors	
Hydraulic ear tag applicator			

Figure 5.23(a) 5.23(b) Supreme Cattle Feeders, LLC, Free run observation of north processing facility when cattle prods were being activated, these same observations caused triggers on the State B setting.



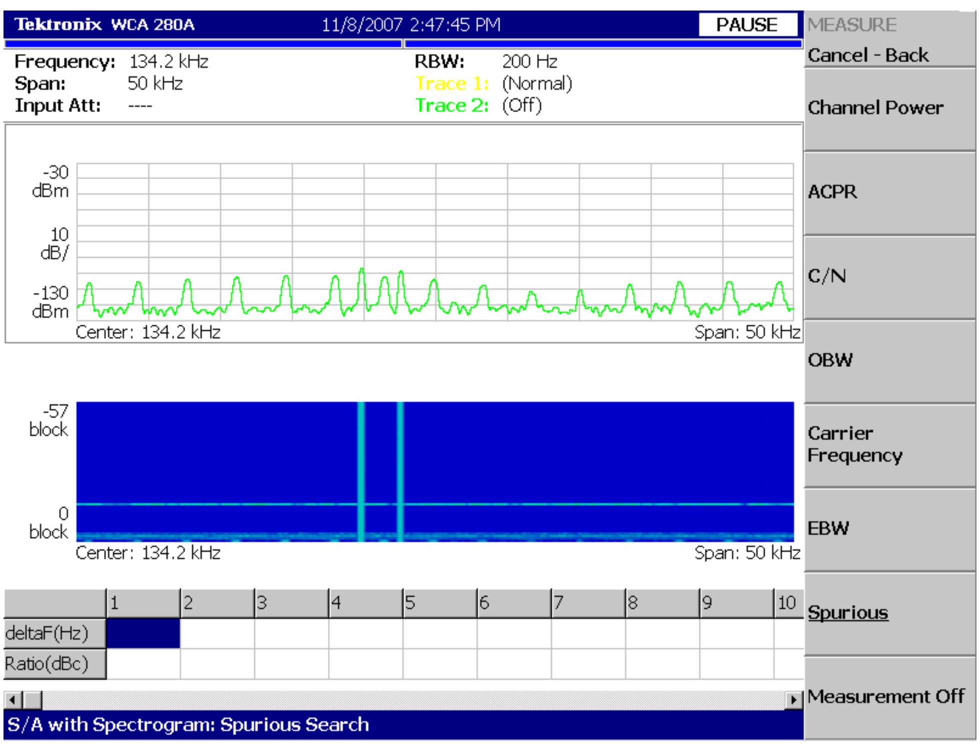


Figure 5.24 Supreme Cattle Feeders, LLC, Free run observation in north processing barn with cattle flowing but no cattle prods being activated.

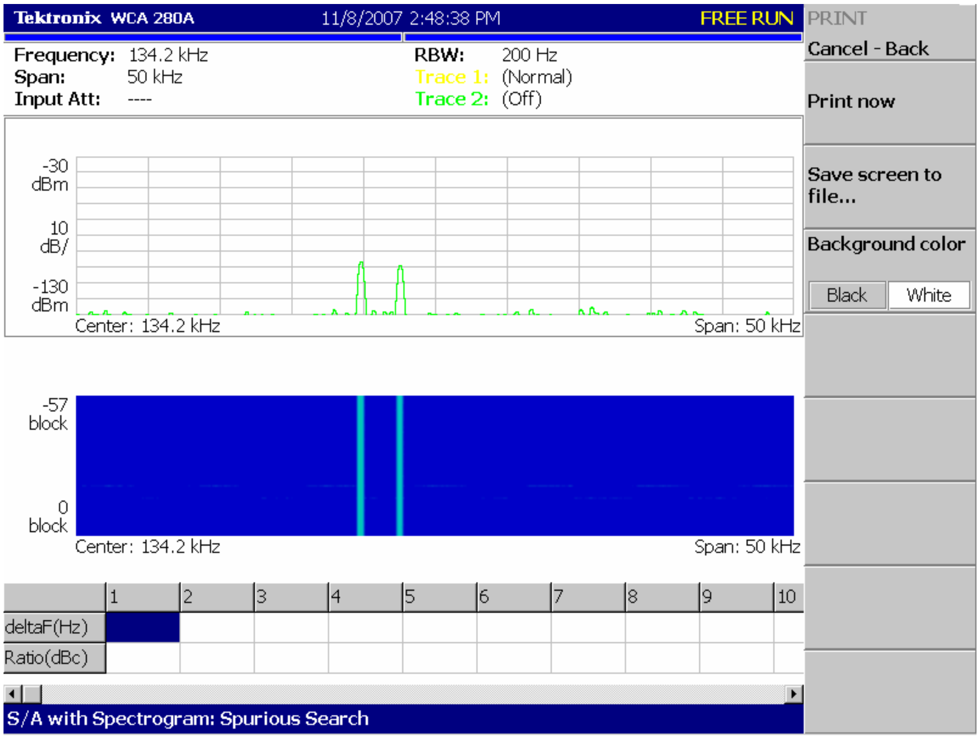


Figure 5.25 Supreme Cattle Feeders, LLC, Free run observation of north load/unload facility – no potential interferences observed

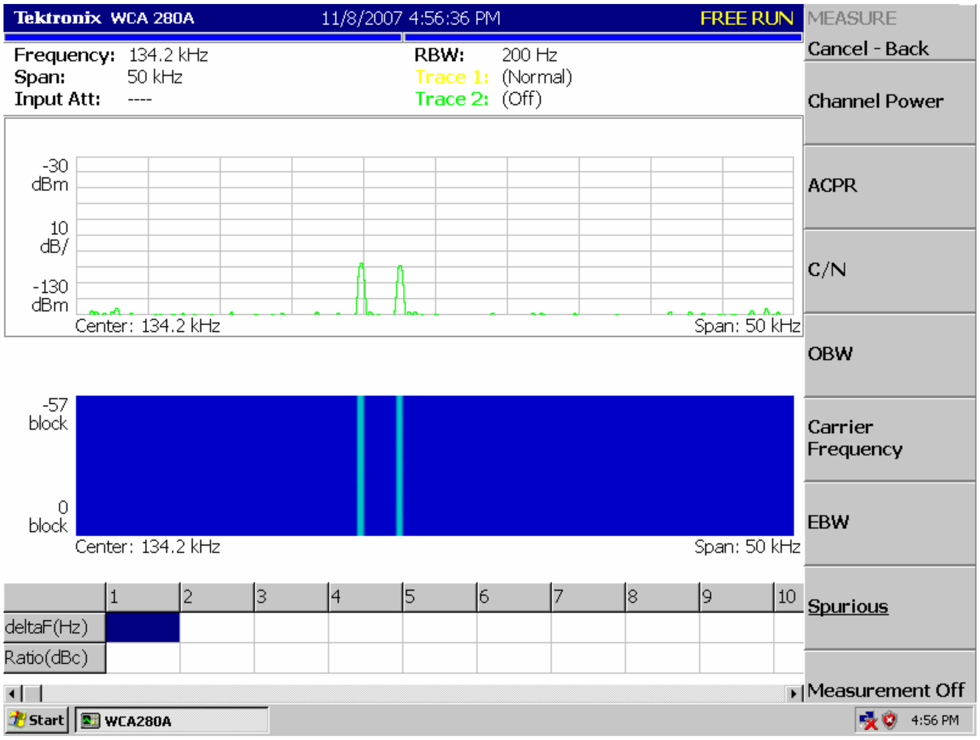
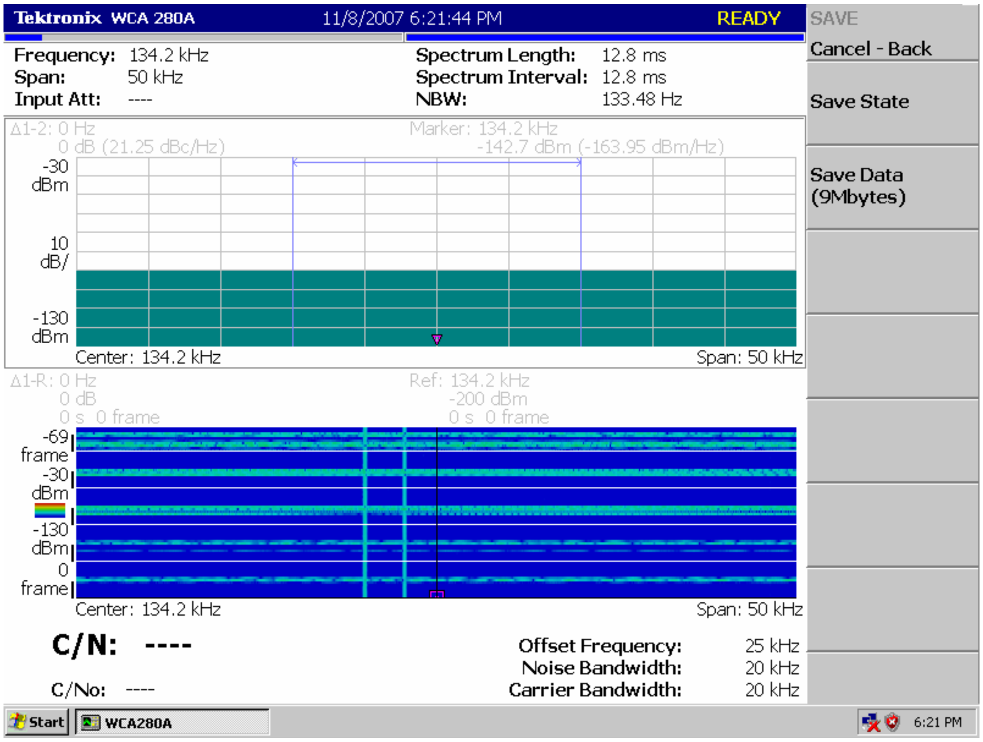


Figure 5.26 Supreme Cattle Feeders, LLC, State B (trigger) setting at north load/unload facility – triggers collected.



In this table, basal level jumps caused multiple peaks to reach the trigger threshold of -90 dBm. Generally, the a single peak did not cause the trigger.

Table 5.21 Great Bend Feeding, Inc, Triggers per hour in each location observed

Date	Hour	Location	Cattle	Trigger/hour	Comments
10/24/2007	8:06 - 9:00 AM	Processing	Yes	1	Hydraulics turned on
10/24/2007	9:06 - 9:15 AM	Processing	Yes	1	Hydraulics turned off
10/24/2007	9:50 - 11:00 AM	Processing	Yes	3	Unknown source of trigger
10/24/2007	11:45 AM - 1:00 PM	Load/Unload	No	1	Unknown source of trigger
10/24/2007	1:08 - 1:46 PM	Load/Unload	No	1	Unknown source of trigger

Table 5.22 Knight Feed Yard, Triggers per hour in each location observed

Date	Hour	Location	Cattle	Trigger/hour	Comments
10/26/2007	1:06 - 1:48 PM	South Processing	Yes	1	Hydraulics turned off
10/26/2007	1:23 - 1:33 PM	BREAK	No	3 Intentional	Pushed button on handheld eID tag reader
10/26/2007	2:06 - 3:06 PM	South Unload/ Load	No	0	
10/26/2007	3:45 - 4:45 PM	North Unload/ Load	No	55	Some triggers intentional: SA antenna moved around, up light pole to electrical wires
10/26/2007	5:03 - 5:55 pm	North Unload/ Load	No	0	

Table 5.23 Ward Feed Yard, Triggers per hour in each location observed

Date	Hour	Location	Cattle	Trigger/hour	Comments
10/31/2007	7:13 - 8:15 AM	Processing	No	3	Hydraulics turned on/off, heating element turned on
10/31/2007	8:20 - 9:25 AM	Processing	Yes	0	
10/31/2007	9:50 - 10:50 AM	Unloading	No	0	
10/31/2007	10:55 - 11:55 AM	Unloading	No	0	
** Note: Weather prohibited collection of data at Load					

Table 5.24 Supreme Cattle Feeders, LLC, Triggers per hour in each location observed

Date	Hour	Location	Cattle	Trigger/hour	Comments
11/8/2007	2:49 - 3:11 PM	North Processing	Yes	115	Triggers occurred with every activation of cattle prod
11/8/2007	4:08 - 4:19 PM	North Processing	Yes	12	First trigger at 4:11 with activation of cattle prods
11/8/2007	4:57 - 6:21 PM	North Unload	No	130	Unknown source of trigger
11/8/2007	6:29 - 7:00 PM	North Unload	No	20	Unknown source of trigger
11/9/2007	9:45 - 10:46 AM	South Processing	No	2	Turned on/off lights
11/9/2007	10:52 - 11:32 AM	South Processing	No	0	
11/9/2007	11:51 - 12:51 PM	South Load	No	0	
11/9/2007	12:56 - 1:56 PM	South Load	No	0	

Figure 5.27 National Beef Packing Co., Dodge City, KS, Free run observation of primary orientation – very low potential interference. 7/2/07, 12:20 PM

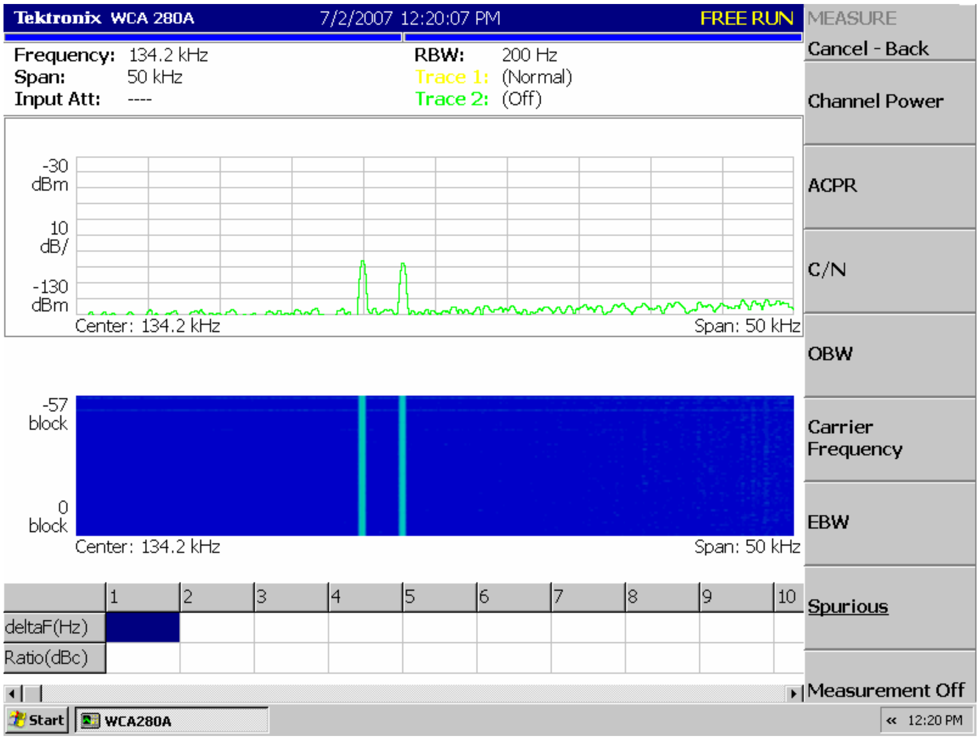


Figure 5.28 National Beef Packing Co., Dodge City, KS, Free run observation of primary orientation – multiple peaks suggesting potential interference; peaks:
115 kHz, -118 dBm;
120 kHz, -116 dBm;
124 kHz, -109 dBm;
130.6 kHz, -117 dBm;
135.9 kHz, -116 dBm;
140 dBm, -109 dBm;
152 kHz, -113 dBm;
160 kHz, -107 dBm
7/3/07, 11:55 AM

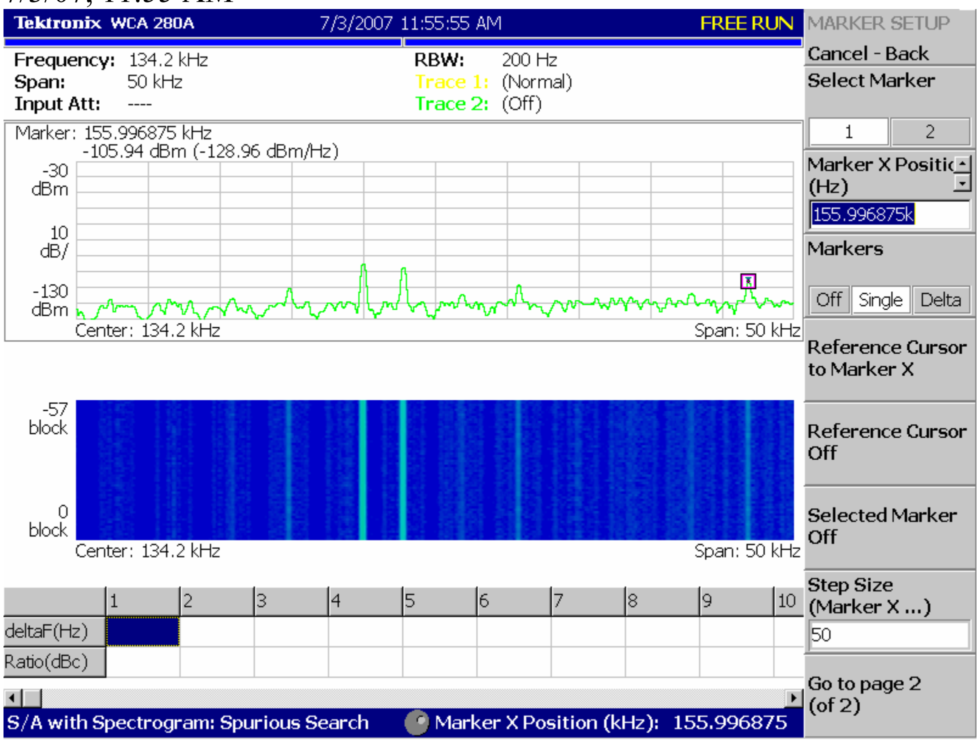


Figure 5.29 National Beef Packing Co., Dodge City, KS, Free run observation of left orientation – raised basal level with two peaks suggesting potential interference. 7/2/07, 10:06 AM

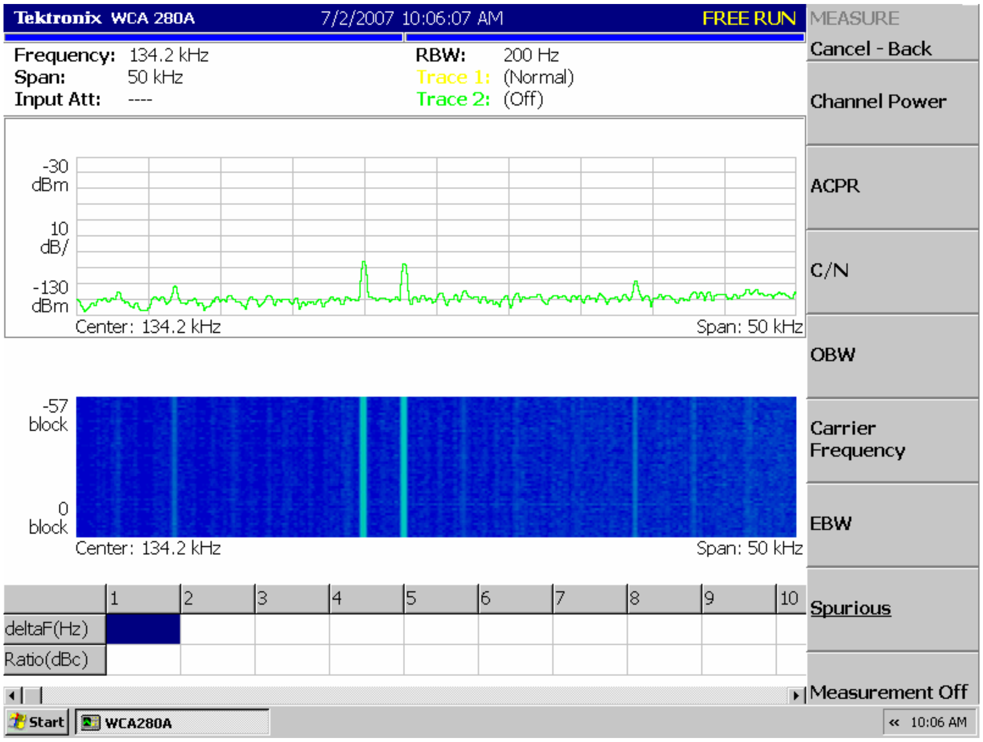


Figure 5.30 National Beef Packing Co., Dodge City, KS, Free run observation of right orientation – two peaks: 155 kHz, -109 dBm; 139 kHz, -112 dBm. 7/2/07, 5:25 PM

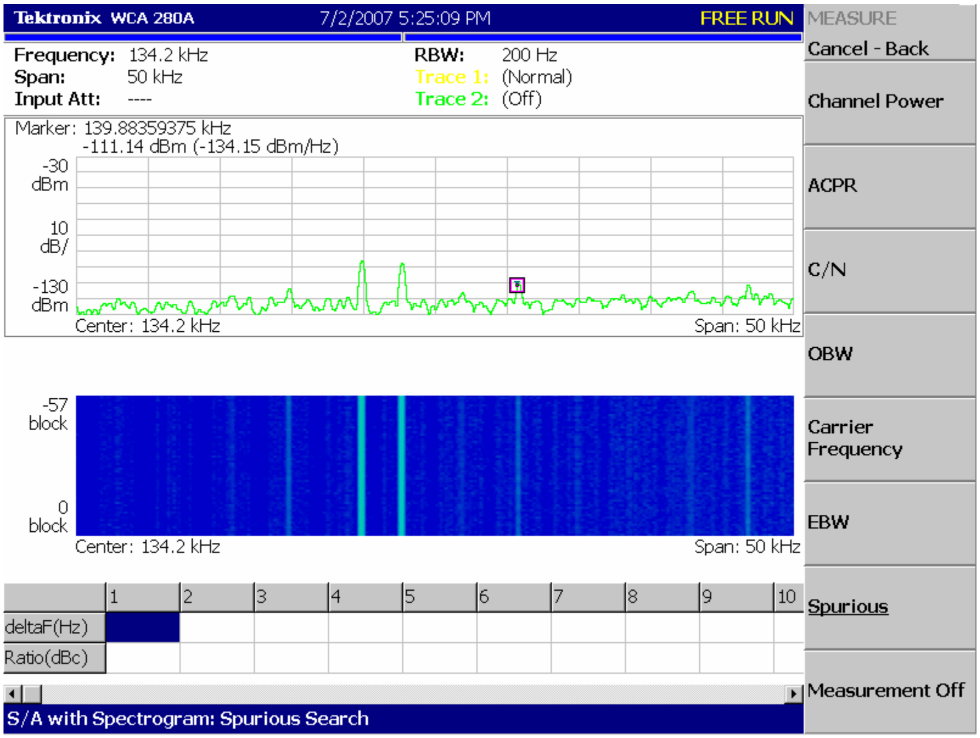


Figure 5.31 National Beef Packing Co., Dodge City, KS, Free run observation of opposite orientation – no significant peaks, basal level below -115 dBm. 7/2/07, 4:16 PM

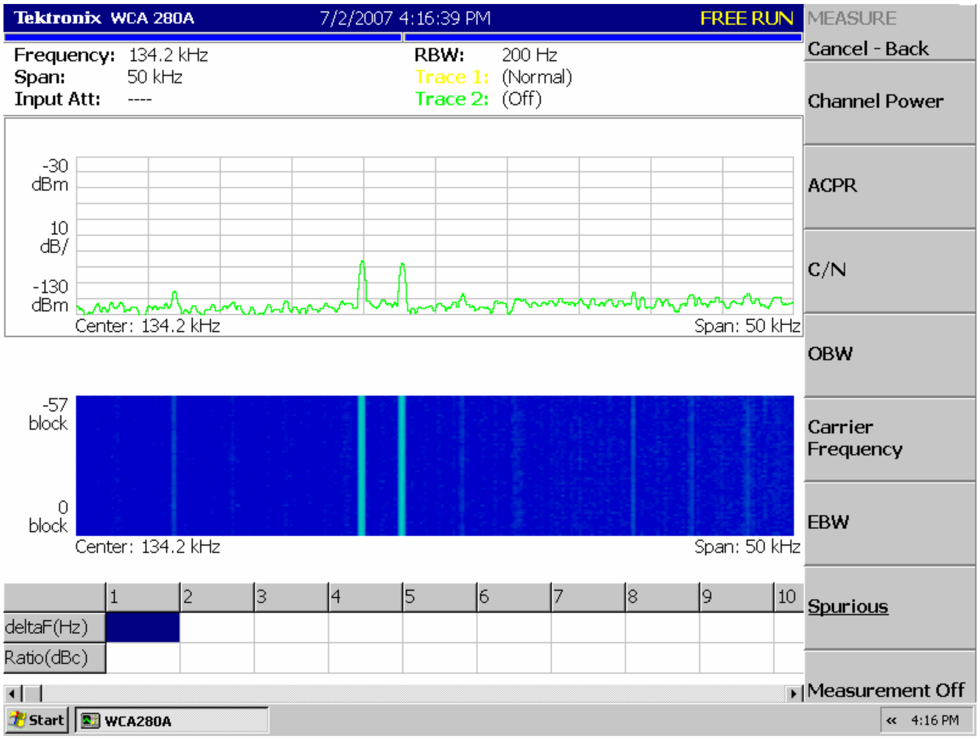


Figure 5.32 National Beef Packing Co., Dodge City, KS, Free run observation of SA antenna in primary orientation located 3.05 m to the right of the original location.

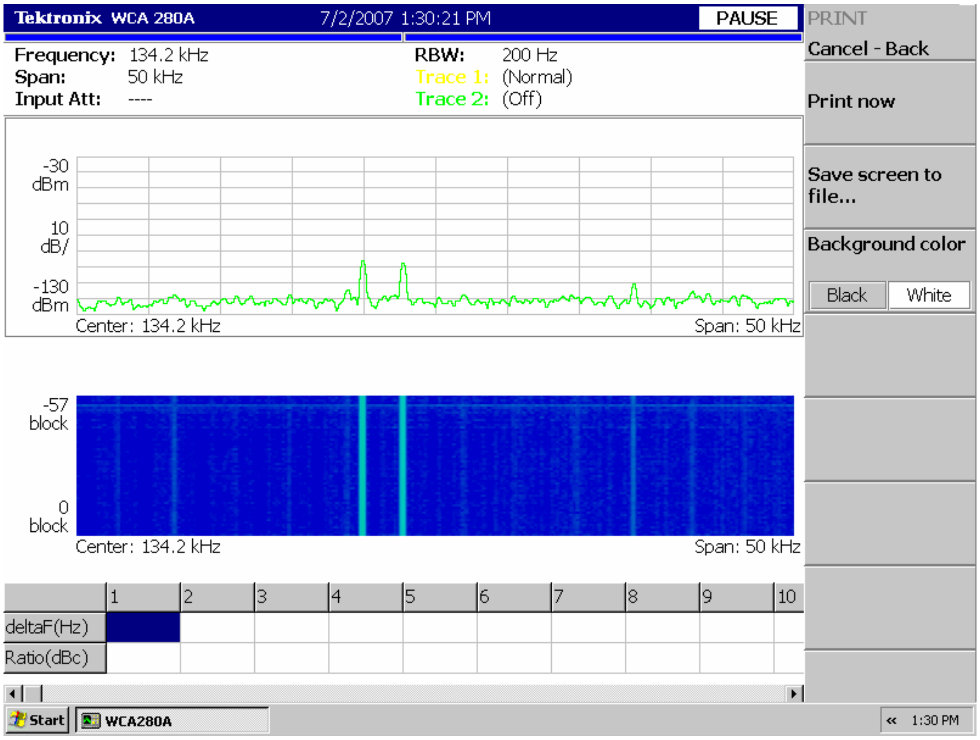


Figure 5.33 National Beef Packing Co., Dodge City, KS, Free run observation of SA antenna in primary orientation located 1.5 m to left of original location.

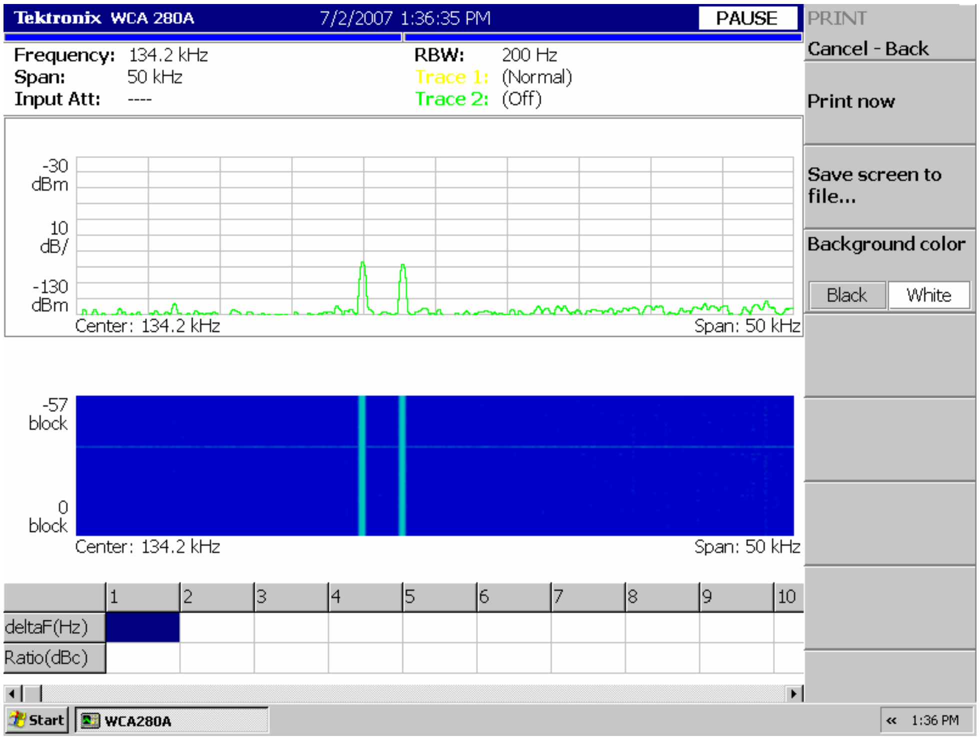


Figure 5.34 National Beef Packing Co., Dodge City, KS, Free run observation of SA antenna in primary orientation located 3.05 m to left of original location.

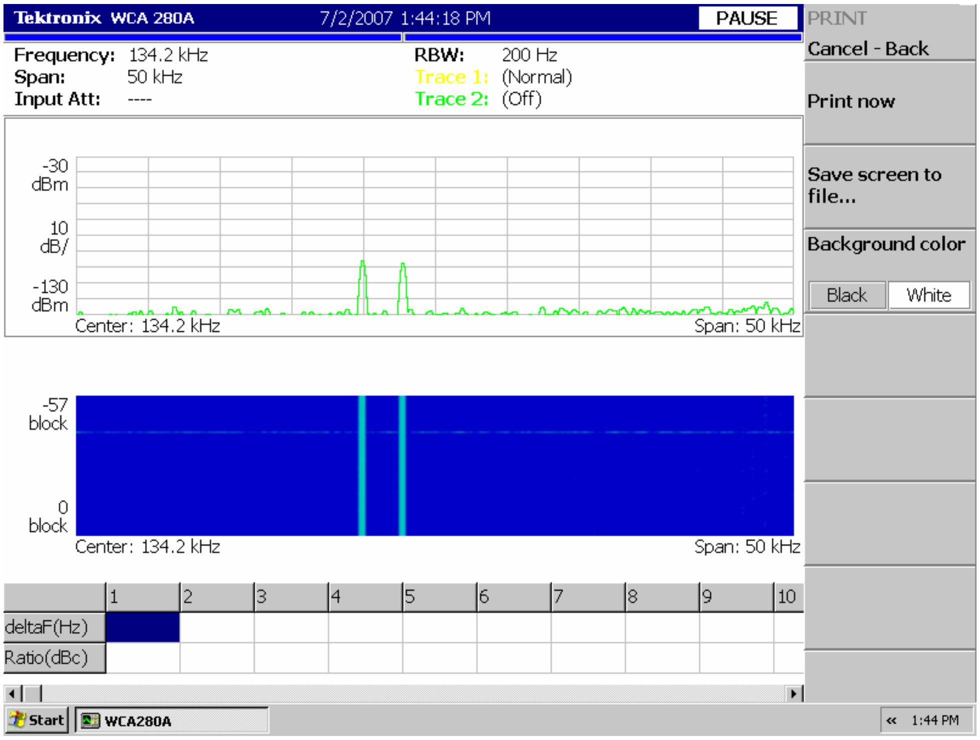


Table 5.25 National Beef Packing Co., Dodge City, KS, Triggers collected in each orientation with hour, run and shift noted.

Date	Hour	Run	Shift	Orientation	Trigger/hour
7/2/2007	5:42 - 6:41 AM	1	A	PRIMARY	26
7/2/2007	6:49 - 7:48 AM	1	A	PRIMARY	NA
7/2/2007	7:58 - 8:55 AM	1	A	OPPOSITE	NA
7/2/2007	8:00 - 8:15 AM	1	BREAK	OPPOSITE	
7/2/2007	9:05 - 10:00 AM	1	A	RIGHT	NA
7/2/2007	10:07 - 11:07 AM	1	A	LEFT	NA
7/2/2007	10:20 - 10:50 AM	1	BREAK	LEFT	
7/2/2007	11:13 AM - 12:13 PM	1	A	PRIMARY	NA
7/2/2007	12:21 - 1:21 PM	1	A	PRIMARY	17
7/2/2007	2:02 - 3:02 PM	2	B	PRIMARY	107
7/2/2007	3:08 - 4:08 PM	2	B	PRIMARY	42
7/2/2007	4:17 - 5:17 PM	2	B	OPPOSITE	13
7/2/2007	5:25 - 6:25 PM	2	B	RIGHT	NA
7/2/2007	5:30 - 5:45 PM	2	BREAK	RIGHT	
7/2/2007	6:32 - 7:32 PM	2	B	LEFT	44
7/2/2007	7:40 - 8:40 PM	2	B	PRIMARY	NA
7/2/2007	7:46 - 8:12 PM	2	BREAK	PRIMARY	
7/2/2007	8:47 - 9:47 PM	2	B	PRIMARY	NA
7/3/2007	5:26 - 6:26 AM	3	A	PRIMARY	21
7/3/2007	6:32 - 7:32 AM	3	A	PRIMARY	NA
7/3/2007	7:39 - 8:39 AM	3	A	OPPOSITE	NA
7/3/2007	7:56 - 8:12 AM	3	BREAK	OPPOSITE	
7/3/2007	9:44 - 10:44 AM	3	A	RIGHT	NA
7/3/2007	10:28 - 10:58 AM	3	BREAK	RIGHT	
7/3/2007	10:50 - 11:50 AM	3	A	LEFT	24
7/3/2007	11:56 AM - 12:56 PM	3	A	PRIMARY	37
7/3/2007	1:02 - 2:02 PM	3	A	PRIMARY	13

Note: This was the first abattoir visit and some data was not recorded due to technicians and technology difficulty.

Figure 5.35 Tyson Fresh Meats, Inc., Emporia, KS, Free run observation of primary orientation, during cleaning (no cattle) – very low basal level interference – nearly an environment without potential interference. 7/19/07, 2:18 PM

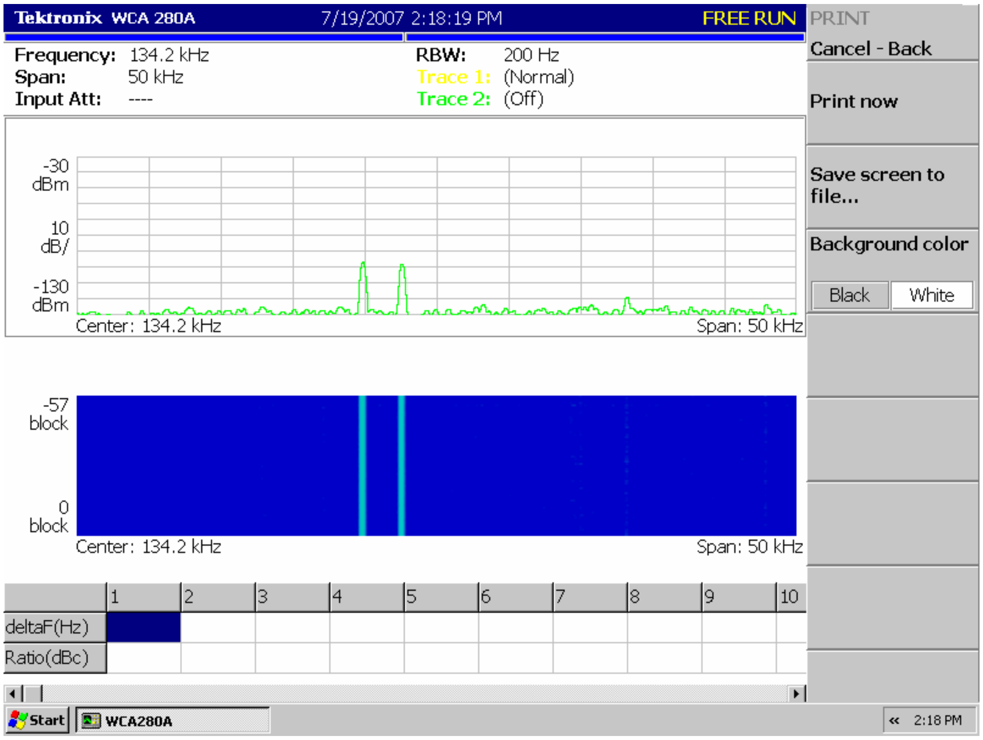


Figure 5.36 Tyson Fresh Meats, Inc., Emporia, KS, Free run observation of primary orientation, with cattle – basal level interference is somewhat higher, especially to the right of 134.2 kHz, but still below -115 dBm. 7/20/07, 6:58 PM

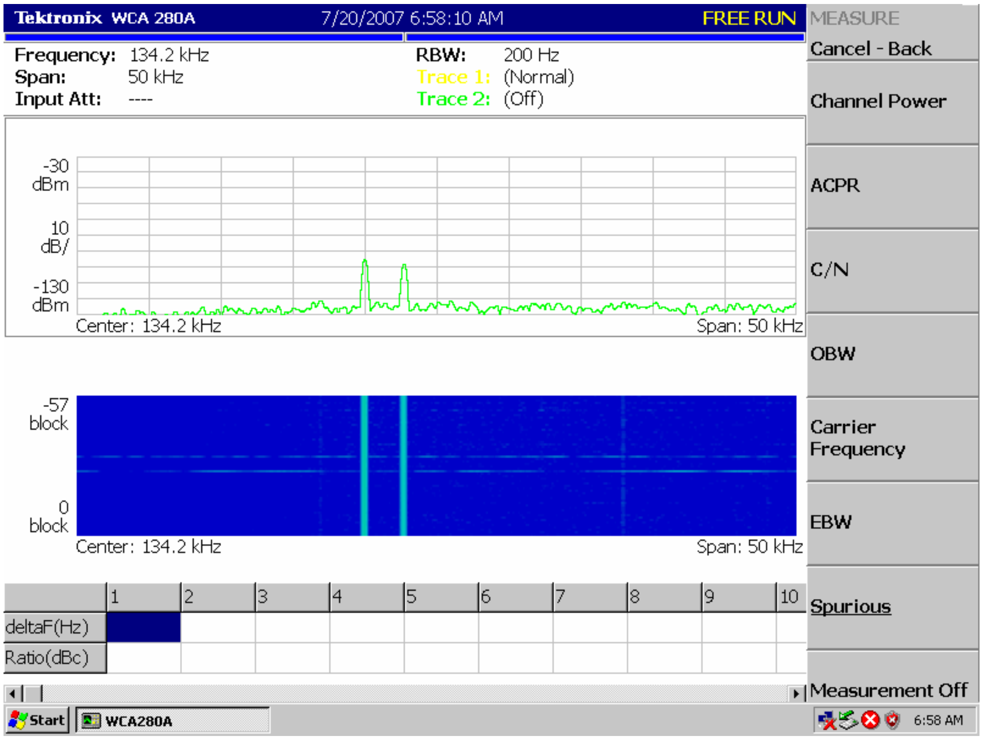


Figure 5.37 Tyson Fresh Meats, Inc., Emporia, KS, Free run observation of left orientation – basal level interference has risen to -120 dBm, in contrast to a -130 dBm observed in the primary orientation. 7/19/07, 6:50 PM

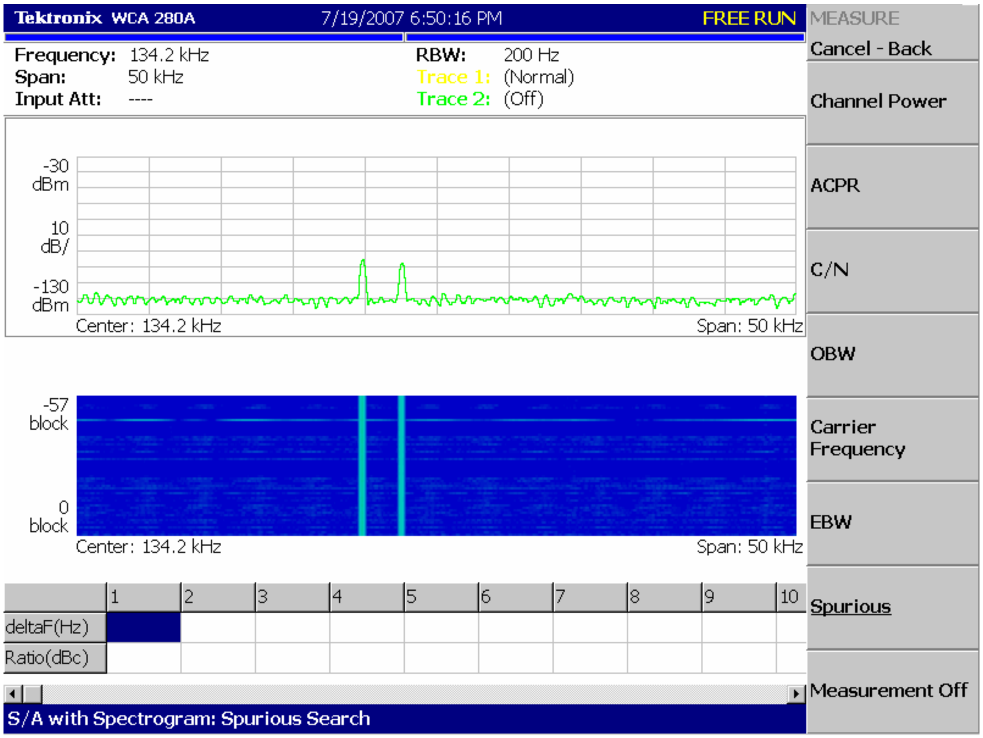


Figure 5.38 Tyson Fresh Meats, Inc., Emporia, KS, Free run observation of right orientation – no potential interference can be observed in this orientation. 7/20/07, 9:10 AM

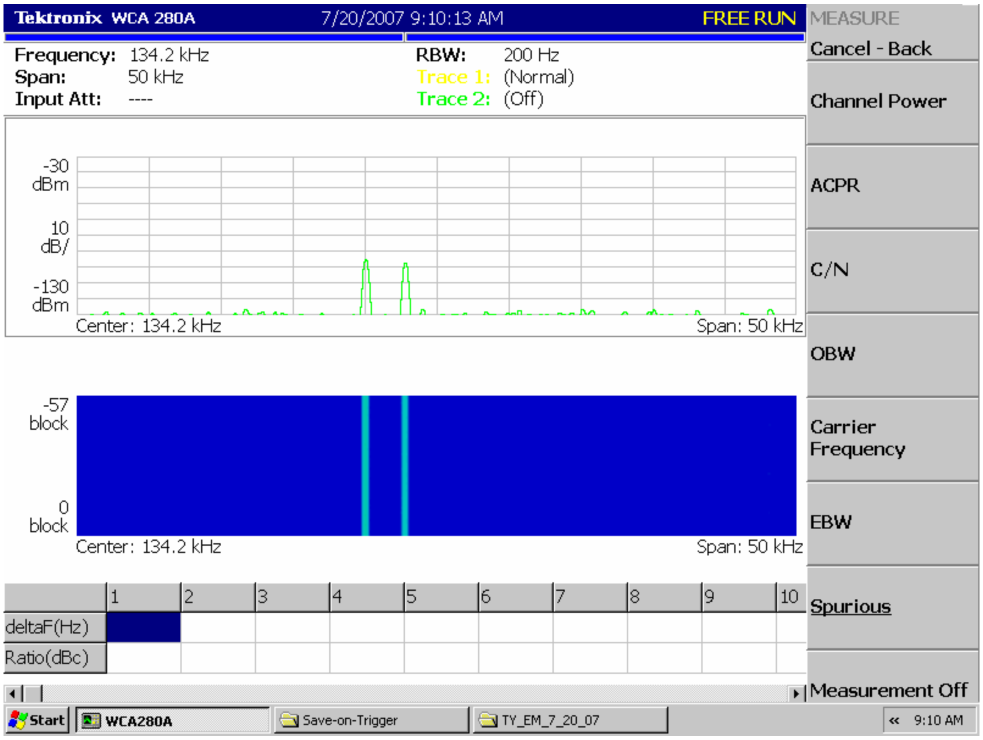


Figure 5.39 Tyson Fresh Meats, Inc., Emporia, KS, Free run observation of opposite orientation – basal level interference rises from left to right; on right-hand side interference level is below -115 dBm and is constant at -120 dBm. 7/19/07, 4:31 PM

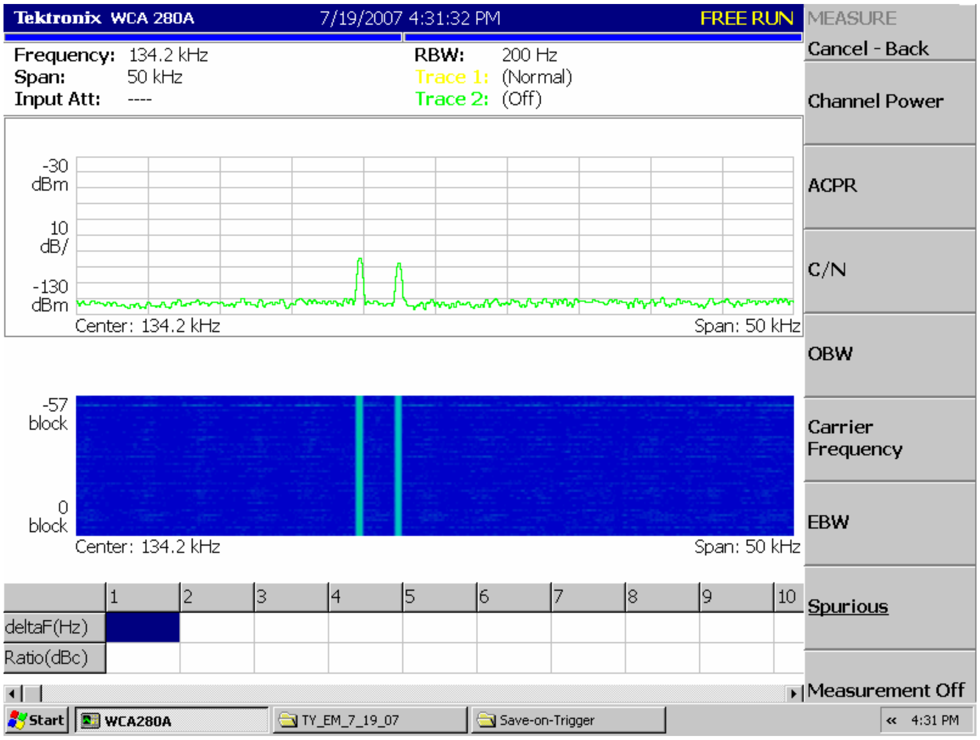


Table 5.26 Tyson Fresh Meats, Inc., Emporia, KS, Triggers collected in each orientation with hour, run and shift noted.

Date	Hour	Run	Shift	Orientation	Trigger/hour
7/19/2007	6:13 - 7:13 AM	1	A	PRIMARY	90
7/19/2007	7:18 - 8:20 AM	1	A	PRIMARY	63
7/19/2007	8:31 - 9:30 AM	1	A	OPPOSITE	156
7/19/2007	8:30 - 8:45 AM	1	BREAK	OPPOSITE	
7/19/2007	9:37 - 10:37 AM	1	A	RIGHT	83
7/19/2007	10:37 - 11:05 AM	1	BREAK	RIGHT	
7/19/2007	10:44 - 11:45 AM	1	A	LEFT	133
7/19/2007	11:53 AM - 12:53 PM	1	A	PRIMARY	151
7/19/2007	1:00 - 2:00 PM	1	A	PRIMARY	149
7/19/2007	2:19 - 3:19 PM	2	B	PRIMARY	26
7/19/2007	3:24 - 4:24 PM	2	B	PRIMARY	64
7/19/2007	4:33 - 5:33 PM	2	B	OPPOSITE	3
7/19/2007	5:40 - 6:00 PM	2	BREAK	RIGHT	
7/19/2007	5:43 - 6:43 PM	2	B	RIGHT	130
7/19/2007	6:51 - 7:51 PM	2	B	LEFT	100
7/19/2007	7:20 - 7:52 PM	2	BREAK	LEFT	
7/19/2007	7:58 - 8:58 PM	2	B	PRIMARY	87
7/19/2007	9:04 - 10:04 PM	2	B	PRIMARY	90
7/20/2007	5:53 - 6:53 AM	3	A	PRIMARY	97
7/20/2007	6:58 - 7:58 AM	3	A	PRIMARY	58
7/20/2007	8:04 - 9:04 AM	3	A	OPPOSITE	73
7/20/2007	8:26 - 8:43 AM	3	BREAK	OPPOSITE	
7/20/2007	9:11 - 10:11 AM	3	A	RIGHT	NA
7/20/2007	10:18 - 11:18 AM	3	A	LEFT	47
7/20/2007	10:40 - 11:10 AM	3	BREAK	LEFT	
7/20/2007	11:25 AM - 12:25 PM	3	A	PRIMARY	89
7/20/2007	12:31 - 1:31 PM	3	A	PRIMARY	86

Figure 5.40 Finney County Tyson Fresh Meats, Inc., Holcomb, KS, Free run observation of primary orientation – no potential interference, all basal level interference is below -120 dBm. 7/24/07, 8:15 AM

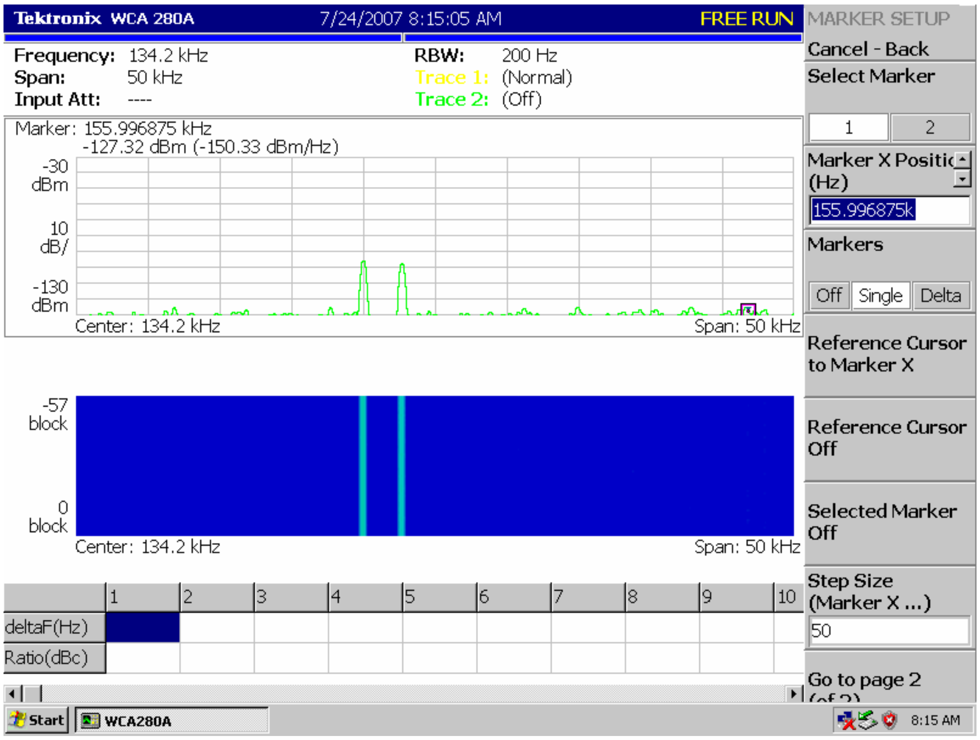


Figure 5.41 Finney County Tyson Fresh Meats, Inc., Holcomb, KS, Free run observation of primary orientation, same day as previous figure, same orientation – basal level interference now has a few peaks however, still below -120 dBm. 7/24/07, 8:25 PM

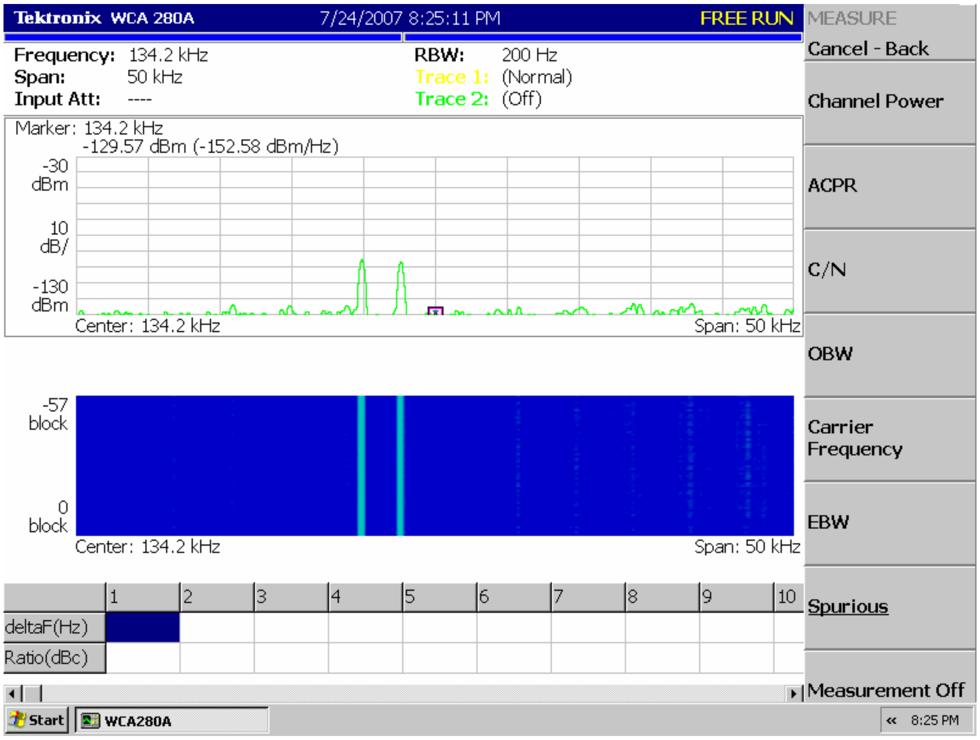


Figure 5.42 Finney County Tyson Fresh Meats, Inc., Holcomb, KS, Free run observation of left orientation – no potential interference, all basal level interference is below -120 dBm. 7/24/07, 7:20 PM

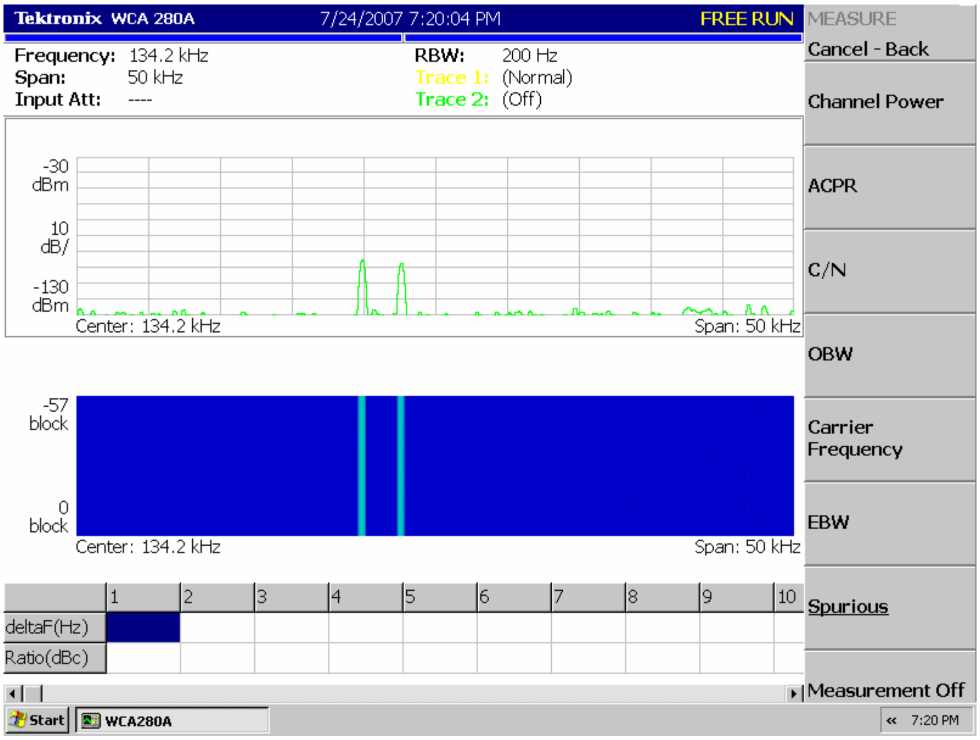


Figure 5.43 Finney County Tyson Fresh Meats, Inc., Holcomb, KS, Free run observation of right orientation – no potential interference, all basal level interference is below -120 dBm. 7/25/07, 10:22 AM

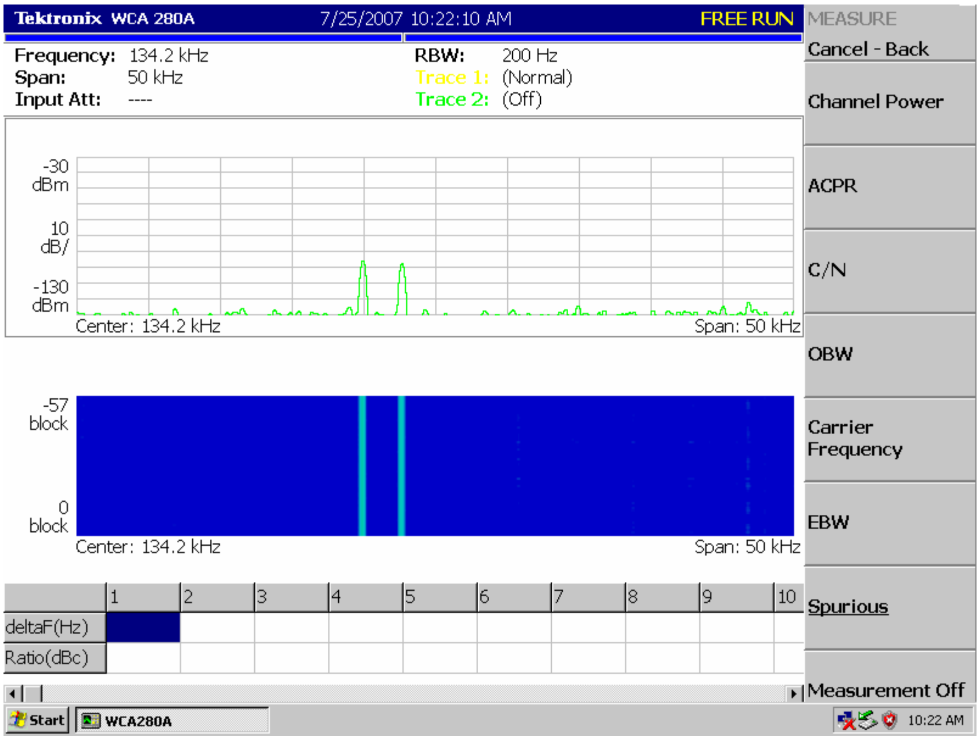


Figure 5.44 Finney County Tyson Fresh Meats, Inc., Holcomb, KS, Free run observation of opposite orientation – no potential interference, all basal level interference is below -120 dBm. 7/25/05, 9:17 AM

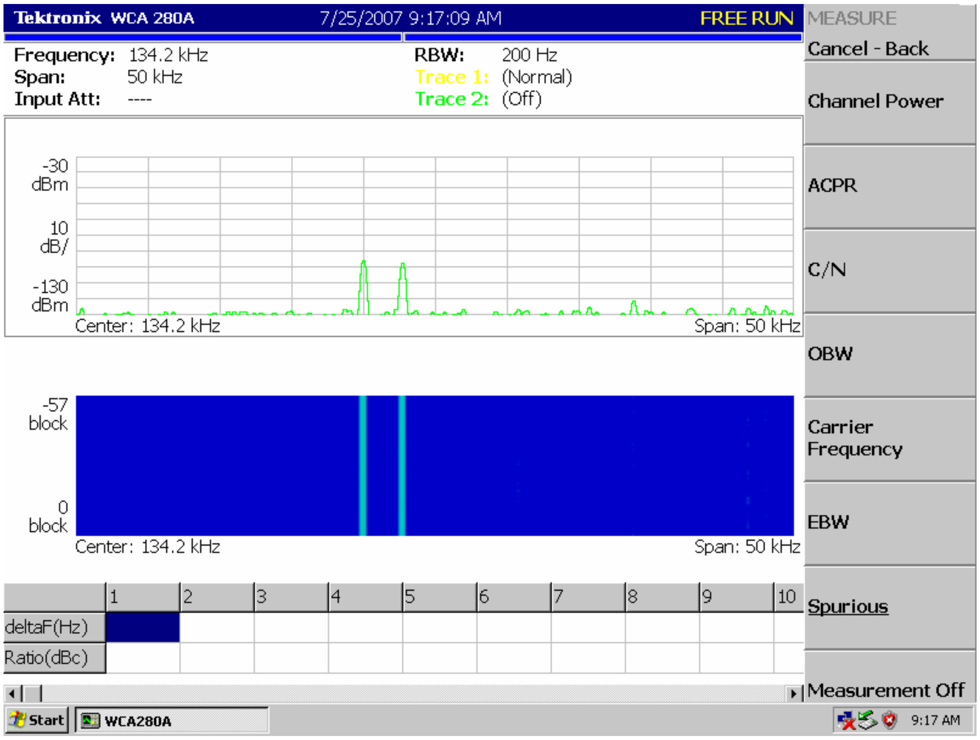


Table 5.27 Finney County Tyson Fresh Meats, Inc., Holcomb, KS, Triggers collected in each orientation with hour, run and shift noted.

Date	Hour	Run	Shift	Orientation	Trigger/hour
7/24/2007	7:10 - 8:10 AM	1	A	PRIMARY	167
7/24/2007	8:15 - 9:15 AM	1	A	PRIMARY	1
7/24/2007	9:20 - 10:21 AM	1	A	OPPOSITE	11
7/24/2007	9:40 - 9:55 AM	1	BREAK	OPPOSITE	
7/24/2007	10:26 - 11:26 AM	1	A	RIGHT	2
7/24/2007	11:33 AM - 12:33 PM	1	A	LEFT	7
7/24/2007	12:10 - 12:40 PM	1	BREAK	LEFT	
7/24/2007	12:40 - 1:40 PM	1	A	PRIMARY	2
7/24/2007	1:45 - 2:45 PM	1	A	PRIMARY	1
7/24/2007	3:01 - 4:01 PM	2	A	PRIMARY	45
7/24/2007	4:06 - 5:06 PM	2	B	PRIMARY	3
7/24/2007	5:10 - 6:10 PM	2	B	OPPOSITE	1
7/24/2007	6:15 - 7:15 PM	2	B	RIGHT	1
7/24/2007	6:15 - 6:30 PM	2	BREAK	NA	
7/24/2007	7:20 - 8:20 PM	2	B	LEFT	7
7/24/2007	8:25 - 9:25 PM	2	B	PRIMARY	5
7/24/2007	9:30 - 10:30 PM	2	B	PRIMARY	3
7/24/2007	9:10 - 9:38 PM	2	BREAK	PRIMARY	
7/25/2007	7:06 - 8:06 AM	3	A	PRIMARY	86
7/25/2007	8:11 - 9:11 AM	3	A	PRIMARY	5
7/25/2007	9:17 - 10:17 AM	3	A	OPPOSITE	2
7/25/2007	9:42 - 9:57 AM	3	BREAK	OPPOSITE	
7/25/2007	10:22 - 11:20 AM	3	A	RIGHT	3
7/25/2007	11:25 AM - 12:25 PM	3	A	LEFT	7
7/25/2007	12:30 - 1:30 PM	3	A	PRIMARY	2
7/25/2007	12:13 - 12:43 PM	3	BREAK	PRIMARY	
7/25/2007	1:35 - 2:35 PM	3	A	PRIMARY	3

Figure 5.45 National Beef Packing Co., Liberal, KS, Free run observation of primary orientation – basal level interferences below -115 dBm. 8/13/07, 4:37 PM

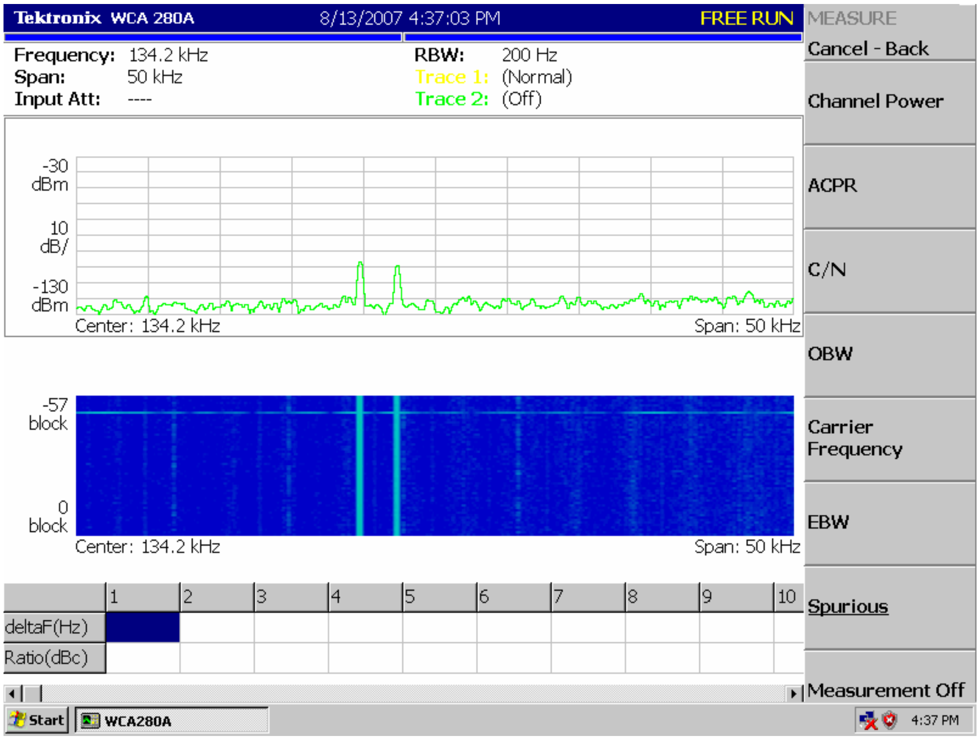


Figure 5.46 National Beef Packing Co., Liberal, KS, Free run observation of primary orientation – more peaks appearing than previous figure, however basal level interference below -115 dBm. 8/14/07, 3:19 PM

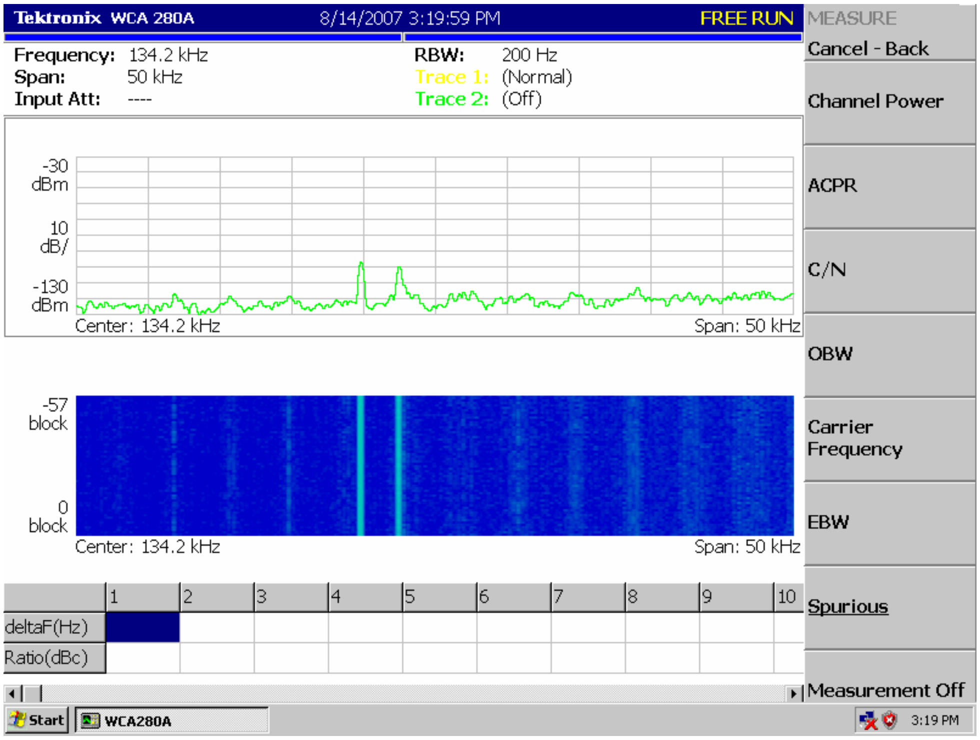


Figure 5.47 National Beef Packing Co., Liberal, KS, Free run observation of left orientation – basal level interference approaching -110 dBm and is more peaked than other observations. 8/13/07, 7:52 PM

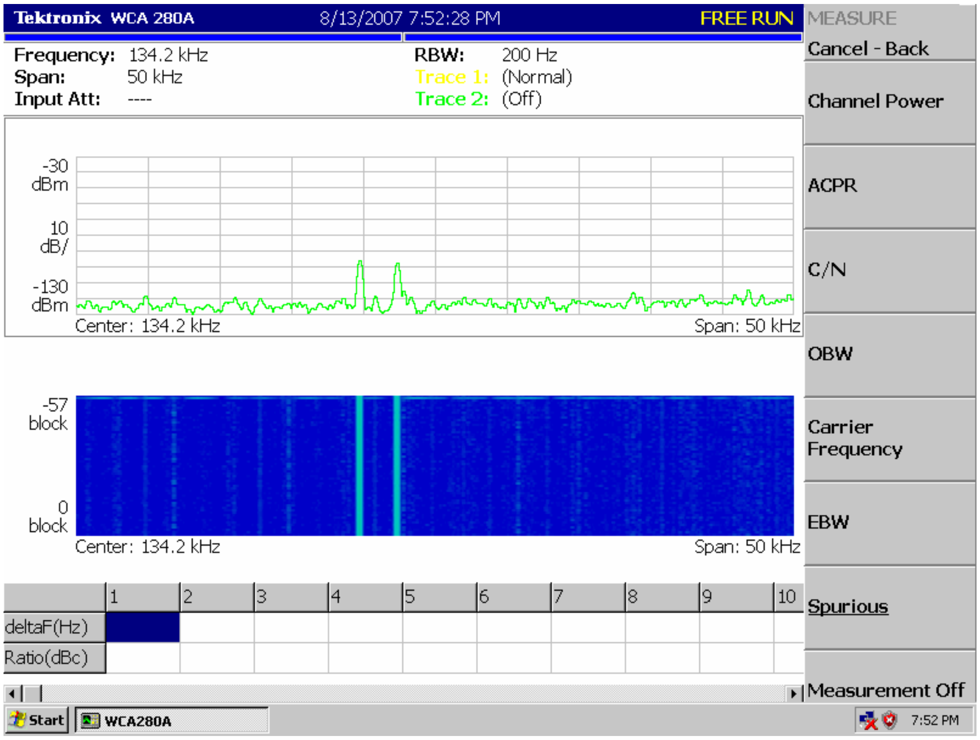


Figure 5.48 National Beef Packing Co., Liberal, KS, Free run observation of right orientation – basal level interference similar to left orientation below -115 dBm. 8/13/07, 6:47 PM

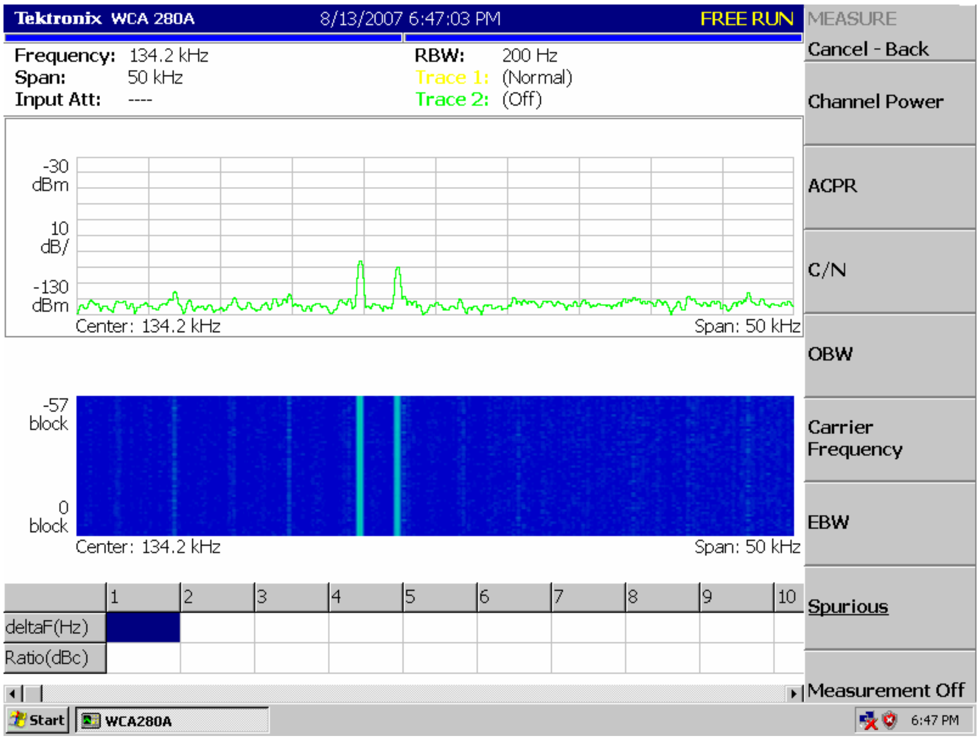


Figure 5.49 National Beef Packing Co., Liberal, KS, Free run observation of opposite orientation – similar observation to previous figures, basal level interference approaching -110 dBm. 8/14/07, 8:15 AM

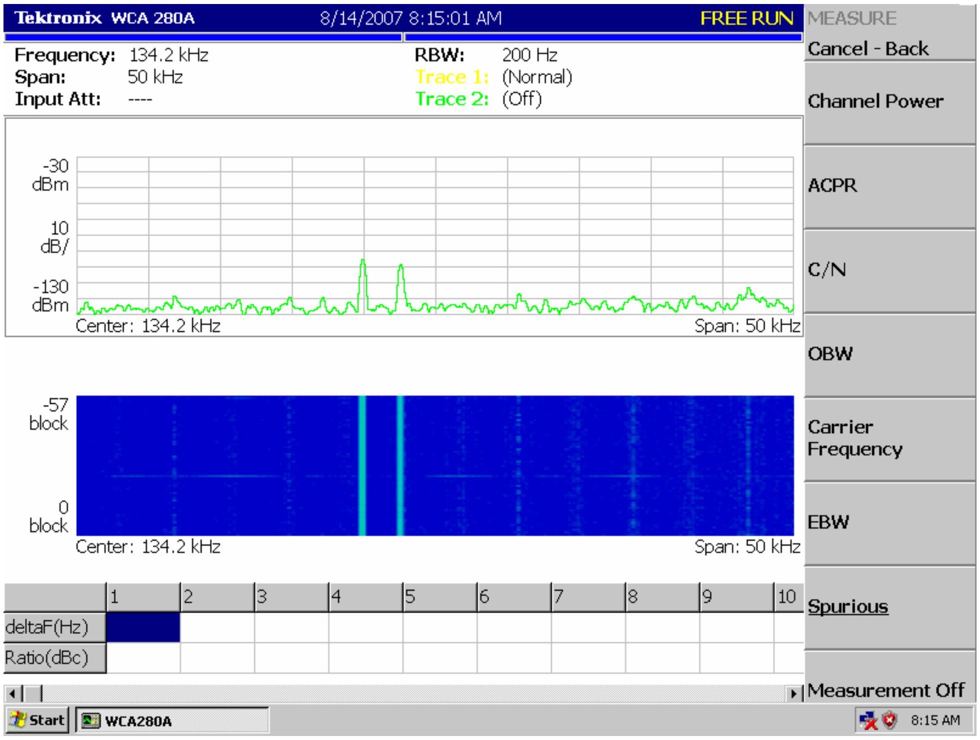


Figure 5.50 National Beef Packing Co., Liberal, KS, Free run observation of RFID tag transceiver being used by abattoir, transceiver is on. The peak in the middle is at 134.2 kHz and significantly louder than -30 dBm.

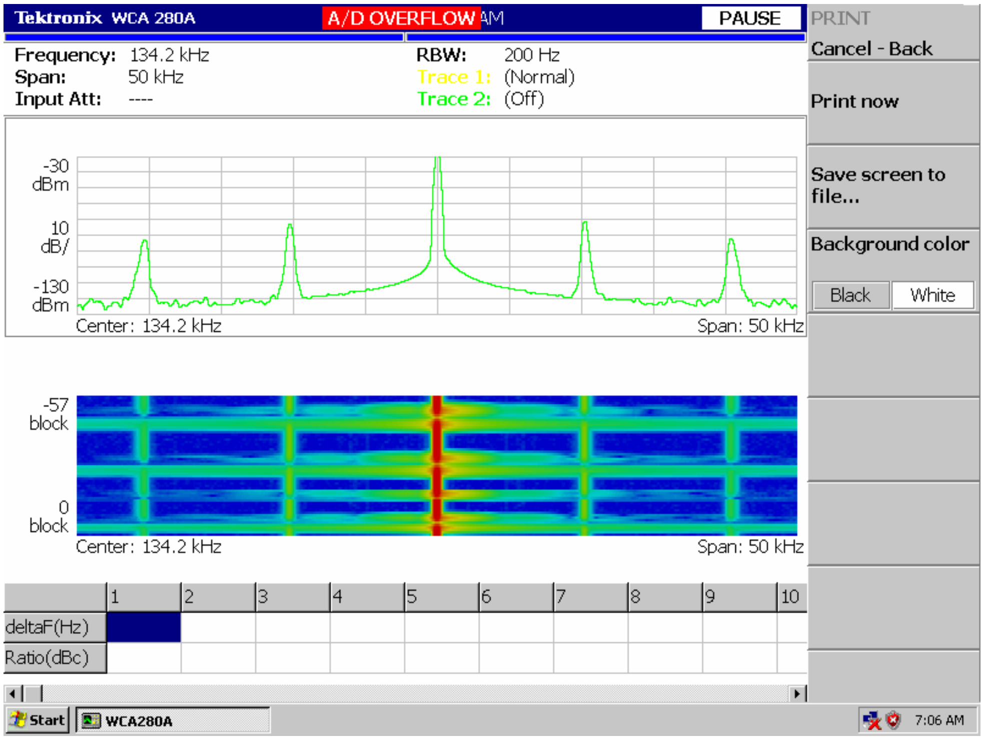


Table 5.28 National Beef Packing Co., Liberal, KS, Triggers collected in each orientation with hour, run and shift noted.

Date	Hour	Run	Shift	Orientation	Trigger/hour
8/13/2007	3:32 - 4:32 PM	1	B	PRIMARY	11
8/13/2007	4:37 - 5:37 PM	1	B	PRIMARY	16
8/13/2007	5:42 - 6:42 PM	1	B	OPPOSITE	16
8/13/2007	5:49 - 6:04 PM	1	BREAK	OPPOSITE	
8/13/2007	6:47 - 7:47 PM	1	B	RIGHT	30
8/13/2007	7:53 - 8:53 PM	1	B	LEFT	5
8/13/2007	8:59 - 9:59 PM	1	B	PRIMARY	31
8/13/2007	10:05 - 11:05 PM	1	B	PRIMARY	82
8/14/2007	7:12 - 8:10 AM	2	A	PRIMARY	NA
8/14/2007	8:15 - 9:15 AM	2	A	OPPOSITE	18
8/14/2007	8:49 - 9:03 AM	2	BREAK	OPPOSITE	
8/14/2007	9:20 - 10:20 AM	2	A	RIGHT	12
8/14/2007	10:25 - 11:29 AM	2	A	LEFT	15
8/14/2007	11:18 AM	2	BREAK	LEFT	
8/14/2007	2:14 - 3:14 PM	3	A	PRIMARY	42
8/14/2007	2:45 - 3:15 PM	3	SHIFT CHANGE	PRIMARY	
8/14/2007	3:20 - 3:40 PM	3	B	PRIMARY	11
8/14/2007	6:18 - 6:55 PM	3	B	PRIMARY	64
8/14/2007	7:01 - 7:52 PM	3	B	OPPOSITE	200
8/14/2007	7:58 - 8:58 PM	3	B	RIGHT	69
8/14/2007	8:18 - 8:45 PM	3	BREAK	RIGHT	
8/14/2007	9:03 - 10:03 PM	3	B	LEFT	54
8/14/2007	10:08 - 11:08 PM	3	B	PRIMARY	51

Figure 5.51 Cargill Meat Solutions, Schuyler, NE, Free run observation of primary orientation – basal level interference -120 dBm to -115 dBm.

Peaks observed at:
112.8 kHz, -103 dBm;
115.0 kHz, -88 dBm;
135.4 kHz, -110 dBm;
158 kHz, -105 dBm
10/19/07, 2:16 PM

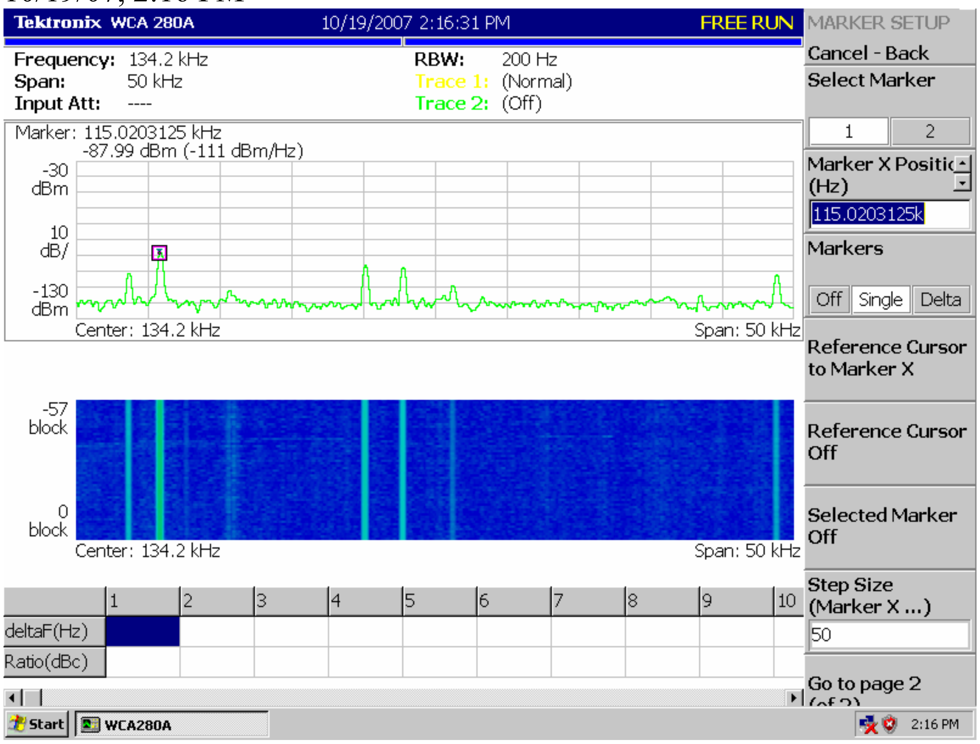


Figure 5.52 Cargill Meat Solutions, Schuyler, NE, Free run observation of primary orientation – many of the previously noted peaks have dropped and basal level remains around -120 dBm, peak at 115 kHz remains. 10/19/07, 3:08 PM

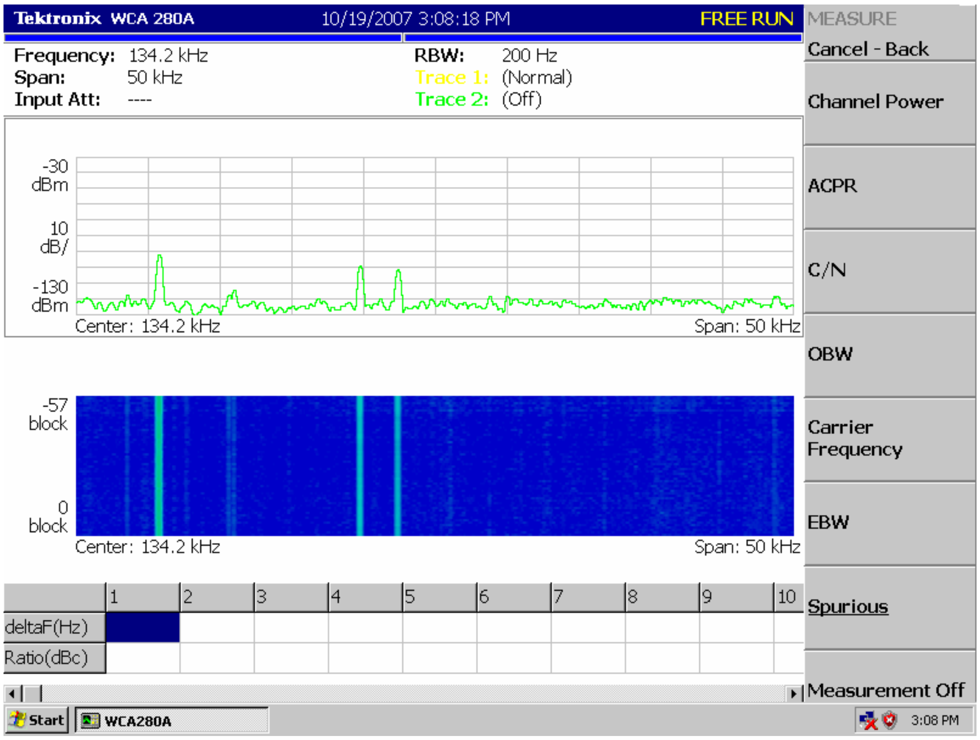


Figure 5.53 Cargill Meat Solutions, Schuyler, NE, Free run observation of left orientation – basal level interference at -120 dBm to -110 dBm, peak at 115 kHz is present. 10/19/07, 10:04 AM

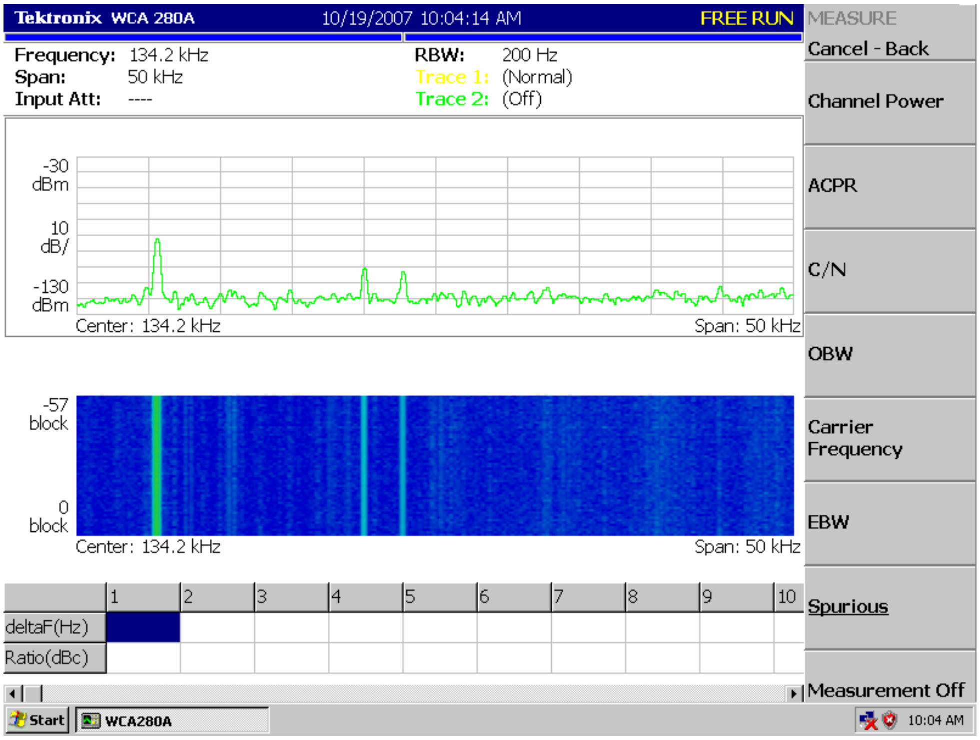


Figure 5.54 Cargill Meat Solutions, Schuyler, NE, Free run observation of right orientation – basal level interference somewhat varied from -120 dBm to -110 dBm with an irregular pattern, peak at 115 kHz. 10/19/07, 8:51 AM

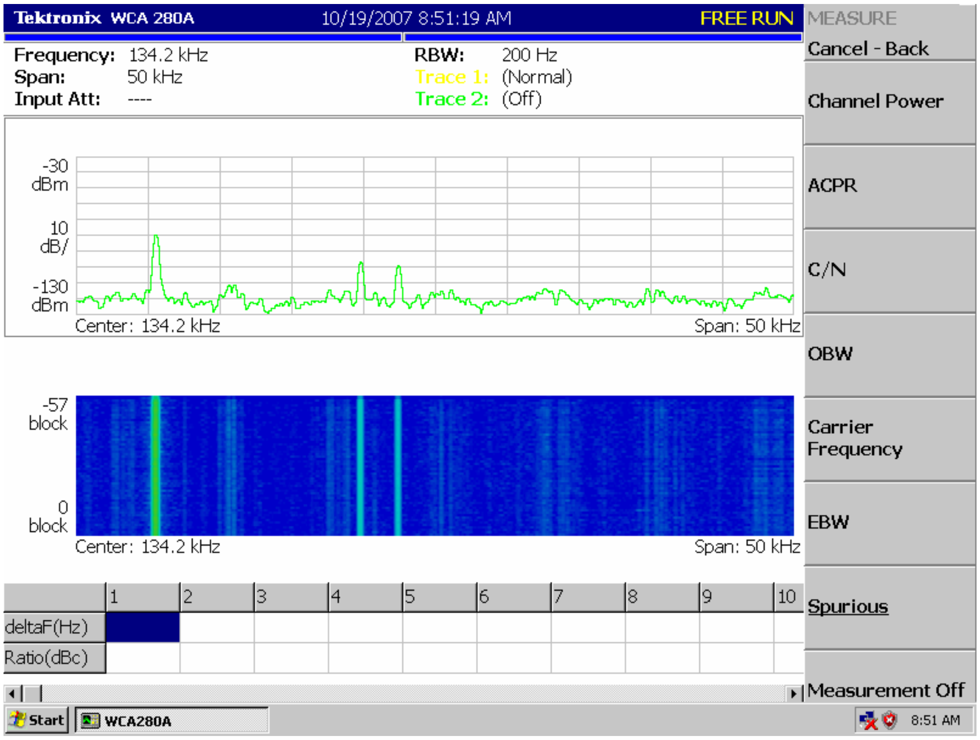


Figure 5.55 Cargill Meat Solutions, Schuyler, NE, Free run observation of opposite orientation – basal level noise rose to -110 dBm, peak at 115 kHz. 10/19/07, 9:35 AM

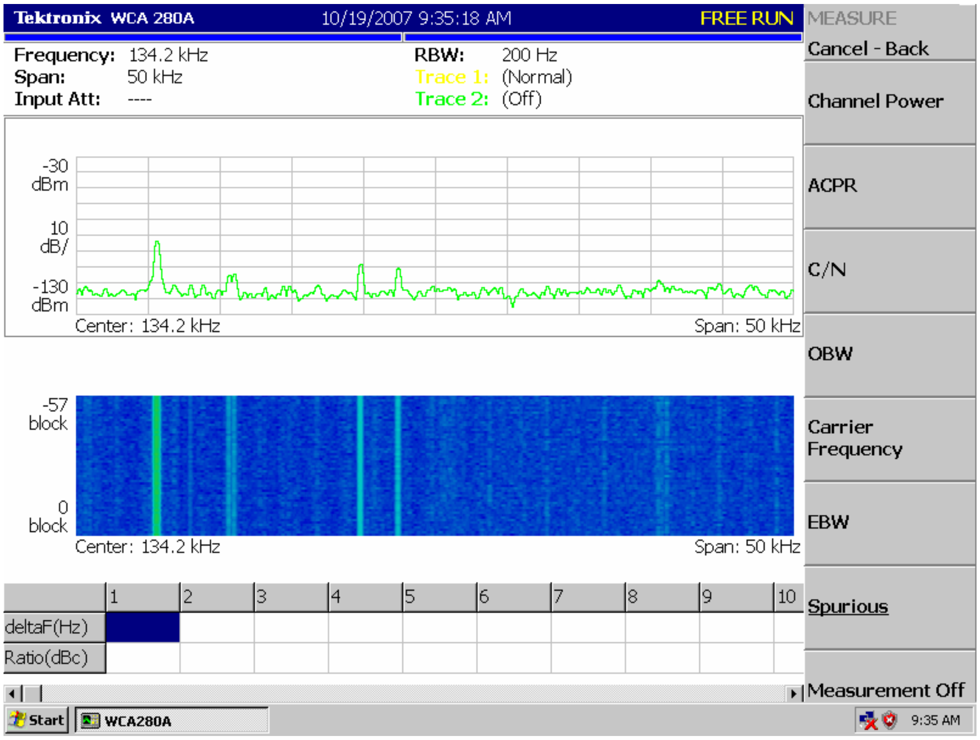


Table 5.29 Cargill Meat Solutions, Schuyler, NE, Triggers collected in each orientation with hour, run and shift noted. This abattoir had a great deal of EMI, therefore the protocol was adjusted and 500 triggers were collected per orientation of the antenna.

Date	Hour	Run	Shift	Orientation	Trigger/hour
10/19/2007	6:00 - 6:10 AM	1	A	PRIMARY	200
10/19/2007	6:20 - 7:00 AM	1	A	PRIMARY	36
10/19/2007	7:06 - 7:14 AM	1	A	PRIMARY	206
10/19/2007	8:10 - 8:26 AM	1	A	PRIMARY	500
10/19/2007	8:23 - 8:26 AM	1	BREAK	PRIMARY	
10/19/2007	8:52 - 9:15 AM	1	A	RIGHT	500
10/19/2007	9:35 - 9:43 AM	1	A	OPPOSITE	500
10/19/2007	10:05 - 10:33 AM	1	A	LEFT	500
10/19/2007	10:54 - 11:09 AM	1	BREAK	PRIMARY	500
10/19/2007	11:25 - 11:35 AM	1	A	PRIMARY	124
10/19/2007	11:36 - 11:53 AM	1	A	PRIMARY	528
10/19/2007	2:20 - 2:47 PM	2	SHIFT CHANGE	PRIMARY	500
10/19/2007	3:09 - 3:16 PM	2	B	PRIMARY	500
10/19/2007	3:43 - 4:00 PM	2	B	RIGHT	595
10/19/2007	4:24 - 4:43 PM	2	B	OPPOSITE	514
10/19/2007	5:05 - 5:36 PM	2	B	LEFT	500
10/19/2007	5:29 - 5:36 PM	2	BREAK	LEFT	
10/19/2007	5:58 - 6:09 PM	2	B	PRIMARY	500
10/19/2007	6:30 - 6:45 PM	2	B	PRIMARY	500

Appendix A - Protocol for evaluation of transponder read distance

To Start:

1. double click on Winwedge icon
2. File C:…..EditID.SW3
3. Activate in Normal Mode
4. Open file of choice into which data will be entered

To Shut down:

1. Save any changes
2. Close files and Winwedge
3. Shut down computer
4. Turn reader off at inverter box

Testing Procedure:

At the KSU Animal Identification Knowledge Laboratory the transponder trolley will be used to measure the distance an RFID tag is read from an antenna. The trolley holds a transponder being tested on a wooden cradle that is attached by Velcro to a belt. The transponder is held stationary on the wooden cradle by its placement on a wooden dowel and is secured from movement with a rubber band that wraps around the transponder and wooden cradle. The transponder/cradle unit is moved electronically toward the transceiver as the belt rotates when activated by a switch. This design minimizes human interferences by removing human hands from the area around the transponder. The transponder moves toward the antenna at a rate of approximately 15 cm/sec. A measuring tape is secured on the trolley adjacent to the rotating belt and is used to determine the distance the tag is from the stationary antenna at the moment it is first interrogated. Upon hearing an audible beeping sound when a transponder is interrogated by the transceiver, the technician will immediately stop the belt rotation and record the distance the transponder is from the antenna.

In the event a transponder reaches the end of the belt nearest the antenna and has not yet been interrogated, a zero indicating a "no read" for that transponder will be recorded. The distance from the end of the belt holding a transponder to the stationary antenna is actually 2.5 inches. Two and ½ inches will then be the minimum read distance distance at which a transponder could be successfully interrogated.

The transponder is in a parallel orientation to the antenna when being tested for read distance distance. The parallel orientation of the transponder to the antenna is when the face of the transponder (imprinted with the visual AIN) approaches the antenna while it is in the cradle being moved toward the antenna to be interrogated. The stationary antennas were placed at the end of the belt reader trolley such that the transponder was in line with the center of the antenna (both vertically and horizontally) as it approached for interrogation.

<u>Summarized testing process:</u>

1. "Standard" transponders will be evaluated for read distance first and every 100 test transponders thereafter. Four of the standard transponders to be used in these evaluations have repeated measurements across a few research trials (Allflex HDX, Farnam, YTex, and Destron (version without metal ring inside)). We will also use six transponders (one from each transponder manufacturer being evaluated in the present study) as "standards" to assess repeatability of transponders measurements and to begin development of an additional pool of standard transponders for future use. These transponders will include one from each of the following manufacturers: Allflex HDX, Allflex FDX, Farnam, Temple, Destron (with metal ring), and Ytex. It is important to recognize that these "standard" transponders do not provide known read distance responses by which we are comparing our read distance testing protocol, but rather include 10 tranponders from which numerous performance measurements have and will continue to be taken in order to assess repeatability of read distance measurements using this testing protocol.

2. There is a total of 3000 transponders to be tested (n=500/category; n=6 manufacturers). Each transponder manufacturer will have its own respective "TEST" bin into which all 500 transponders will be placed. A single transponder will be randomly selected from each "TEST" bin and read distance measurements assessed in the following order:

   YTex
   Allflex HDX
   Temple
   Farnam
   Allflex HDX
   Destron

   This stratification across transponder category during evaluation will ensure appropriate distribution of transponder category across all the technicians performing the evaluations.

3. Record the visual identification number (this is the number in black marker; 1 to 3000) in both the computer spreadsheet and research data book (in black ink).

4. Place the transponder on the wooden cradle and secure with the rubber band. The wooden cradle should be located at the end of the belt on the trolley that is the farthest from the antenna.

5. Turn the switch on to rotate the belt and move the transponder toward the antenna.

6. Upon hearing an ***audible beep from the computer***, immediately stop the belt rotation. The audible from the computer will be used as a stop signal because some reader brands do not have their own audible, but rather a light indictor.

7. Record the read distance (to the nearest 0.5 inch) at which the transponder (measure at the face of the transponder, not the wooden cradle) is from the antenna using the measuring tape secured to the trolley on both the computer spreadsheet and in the research data book (in black ink). In the event no interrogation occurs by the time the transponder/cradle unit has reached the downturn point on the belt nearest the antenna, a "no read" should be recorded.

8. Place the transponder just tested into the "COMPLETED" bin for the corresponding transponder category.

9. Upon completion of a single read distance test for all 3000 transponders, all transponders should be placed in their respective category's "TEST" bin for completion of a duplicate read distance test on all 3000 transponders.

Appendix B - Protocol for evaluation of resonance frequency and voltage response of transponders

Oscilloscope and Function Generator Setup, Assembly, and Instructions For Evaluation of Resonance Frequency and Voltage Response of Transponders

Cable/Antennae Attachment

1. Connect antennae cable from the port on the probe labeled "function generator" to the port labeled "Output/50Ω" on the function generator.
2. Connect antennae cable from port on the probe labeled "scope" to the port on the oscilloscope labeled "Channel 1."
3. When conducting tests on HDX tags, attach an additional cable from the port on the function generator labeled "Output/TTL" to the port on the oscilloscope labeled "Channel 2."

Power-on and FDX Setup and Preparation

FDX Oscilloscope Setup

1. Begin by powering on both function generator and oscilloscope.
2. Set the oscilloscope to the preset mode assigned for FDX tags in channel 1.
   a. Press "Save/Recall" button.
   b. On the bottom of the oscilloscope screen press the soft key under the title "Recall Saved Setup."
   c. On the right side of the oscilloscope screen press the soft key next to the title "Setup 1."
   d. Press "Menu Off."

Note: This will activate a previously saved version on the oscilloscope to measure FDX tags. When performing tests on all FDX tags, this process needs only to be conducted once.

FDX Function Generator Setup

1. For quick start press the "Recall/Menu" button located on the lower half of the generator. A new menu on the generator display will appear.
2. While viewing the display, turn the variable knob located on the upper right corner on the generator so that the words "Setup 1" is highlighted in the display screen.
3. Once that selection is highlighted, press the soft key next to the word "Recall" located on the right side of the function generator display screen (second rectangular button from the top).
4. This will allow the saved settings for FDX tags to be activated.

In case saved settings are lost, to set function generator to test FDX tags perform the following:

1. In the column labeled "Function" on the generator, press the top button labeled "Sine."
2. Next, to the right of the "Sine" button, press a button labeled "Continuous."
3. Then, press the "Amplitude/High" button once so that the "Ampl" row is highlighted in the display screen. Using the left/right arrow buttons and the key pad just below those, set the amplitude to 1.00 Vpp. and press the soft key next the letters "Vpp" to set your units. Then press "Enter."
4. Finally, press the "Frequency/Period" button once so that the row "Freq" is highlighted in the display screen. Using the left/right arrow keys and the key pad, set the frequency to 134.2 and press the soft key next the units labeled "kHz" and then press "Enter."

FDX Tag Reading and Recording

Amplitude

1. Place FDX tag on top of probe centering the tag on top of the stud that protrudes out from the top of the fixture.
2. Begin by pressing the "Amplitude/High" button once on the generator. Using the left/right arrow keys, set the cursor in the tens placeholder just to the right of the decimal point. Turn the dial downward a significant amount until it is obvious the tag has not been activated (a straight line with no modulations represents a deactivated or an off tag).
3. Gradually begin turning the dial upwards one click at a time until the display screen on the oscilloscope shows modulation. Before recording amplitude, the modulations need to be symmetrical and absent of any "long extended horizontal lines" or "bell-shaped figures." If neither of these structures are present, record the amplitude.

Note: Some particular amplitude measurements may appear to turn on the tag but it may seem that the tag may be "half-on" or being "turned-on" therefore scroll the dial upward and back a little more to verify a true activation amplitude.

Resonance Frequency

1. While leaving the amplitude set at the number previously discovered, press the "Frequency/Period" button once.
2. Begin by using the left/right arrow keys and place the flashing cursor under the tens position (the first position to the right of the decimal point) and scroll the dial upward until it is apparent the tag is not active. Then gradually decrease the dial by turning downward one click at a time until you observe the number at which the tag goes from inactive to active. Make sure that the tag is completely active with symmetrical modulations. Record that number.

Note: Depending upon the tag type, 134.2 K Hz may be a low frequency at which the tag is still inactive causing the viewer to scroll downward resulting in the high range of the resonance frequency being lower than 134.2 K Hz.

3. Now scroll the dial a significant amount downward until it is apparent that the tag is not active. Gradually begin to increase the dial upward one click at a time until you observe the number at which the tag goes from inactive to active. Make sure the tag is completely active with symmetrical modulations. Record that number.

Note: Depending upon the tag type, 134.2 K Hz may be a lower frequency at which the tag is already inactive causing the viewer to have to scroll upward resulting in the lower range of the resonance frequency being greater than 134.2 K Hz.

4. Remove the current tag from atop the stud on top of the probe.

5. To reset the function generator to the original FDX test settings, refer to ***Function Generator Setup steps 1-3.***

Calculating Resonance Frequency
Example:
Low Range Number of Frequency: 131.9 K Hz
High Range Number of Frequency: 133.8 K Hz 133.8 – 131.9 = 1.9 / 2 = 0.95

131.9 + 0.95 = 132.85 K Hz is the resonance frequency for that particular tag.

Powering-on and HDX Setup and Preparation

If not already powered on, turn on function generator and oscilloscope.Attach an additional antennae cable from the port labeled "Output/TTL" on the function generator to the port on the oscilloscope labeled "Channel 2."

HDX Oscilloscope Setup

1. Press the "Save/Recall" button on top of the oscilloscope and a menu will appear. On the bottom of the oscilloscope screen press the soft key under the title "Recall Saved Setup." On the right side of the oscilloscope screen press the soft key next to the title "Setup 2." Blue bars should appear on the oscilloscope screen when correctly performed.
2. Press "Menu Off."

Note: This will activate a previously saved version on the oscilloscope for measuring HDX tags. When performing tests on all HDX tags, this procedure needs only to be conducted once.

HDX Function Generator Setup

1. To preset the Amplitude and Frequency on the function generator, press the "Recall/Menu" button in center of the function generator. A new screen will appear on the function generator display screen.
2. Use the dial to highlight "Setup 2."
3. Press the soft key on the right of the display screen next to the word "Recall."
4. Press the "Channel/On" button located just above the "Output/50Ω" cable port.

In case saved settings are lost, to set function generator to test HDX tags perform the following:

1. In the column labeled "Function" on the generator, press the top button labeled "Sine."
2. Next, four buttons to the right of the "Sine" button, press a button labeled "Burst."
    a. The word "Gate" will appear in the function generator display screen. Press the soft key next to the display screen beside that word.
    b. Next, press the soft key just below that labeled "more/1 of 2." A new menu on the side of the display screen will appear. Press the soft key next to the words "Trigger Interval." This should highlight a row on the display screen entitled "Interval." Using the keypad, type in 100 and press the soft key next to the units titled "ms." Then press "Enter."

3. Then, press the "Amplitude/High" button once so that the "Ampl" row is highlighted in the display screen. Using the left/right arrow buttons and the key pad just below those, set the amplitude to 1.00 Vpp. and press the soft key next the letters "Vpp" to set your units. Then press "Enter."
4. Finally, press the "Frequency/Period" button once so that the row "Freq" is highlighted in the display screen. Using the left/right arrow keys and the key pad, set the frequency to 134.2 and press the soft key next the units labeled "kHz" and then press "Enter."

HDX Tag Reading and Recording

1. Place an HDX tag on top of probe centering the tag on top of the stud that protrudes out from the top of the fixture.
2. Press the "Amplitude/High" button once. Adjust the amplitude using the tens position (number position directly right of the decimal point) and slowly begin turning the dial upward one click at a time. The viewer will eventually begin to notice the blurred area on the oscilloscope begin to expand horizontally to the right.
   a. Continue to scroll the dial upwards until the extending region covers almost all of four squares on the oscilloscope screen.
   b. Record the amplitude where the blurred region made its last move horizontally to the right. Any amplitude supplied after that point, the blurred region will expand vertically.

Note: The blurred region will only approach that final line at the end of the fourth square. It will never actually touch that line because the turn on line is 15 msec and the final line is 16 msec. Therefore as the viewer gradually turns the dial upwards the blurred region will move slowly to the right.

HDX Resonance Frequency

1. While maintaining the same amplitude that you just recorded, press the "Frequency/Period" button once.
2. Begin by turning the dial slowly upward and you should observe that blurred region move to the left significantly. Now, gradually begin turning the dial downward until the viewer notices the same activity as before when recording the necessary amplitude. Record the number where the blurred region makes its final horizontal move to the right. Record this number as the high number in the frequency interval.
3. Turn the dial downward significantly until the viewer observes the blurred region back off the line significantly towards the left again. Now, the viewer should turn the dial upward. The blurred region will begin to move right again. Record the number where the blurred region makes its final horizontal move to the left. This is the high number in the frequency interval.
3. Calculate the resonance frequency as mentioned in **Calculating Resonance Frequency** using the low and high frequency numbers obtained.

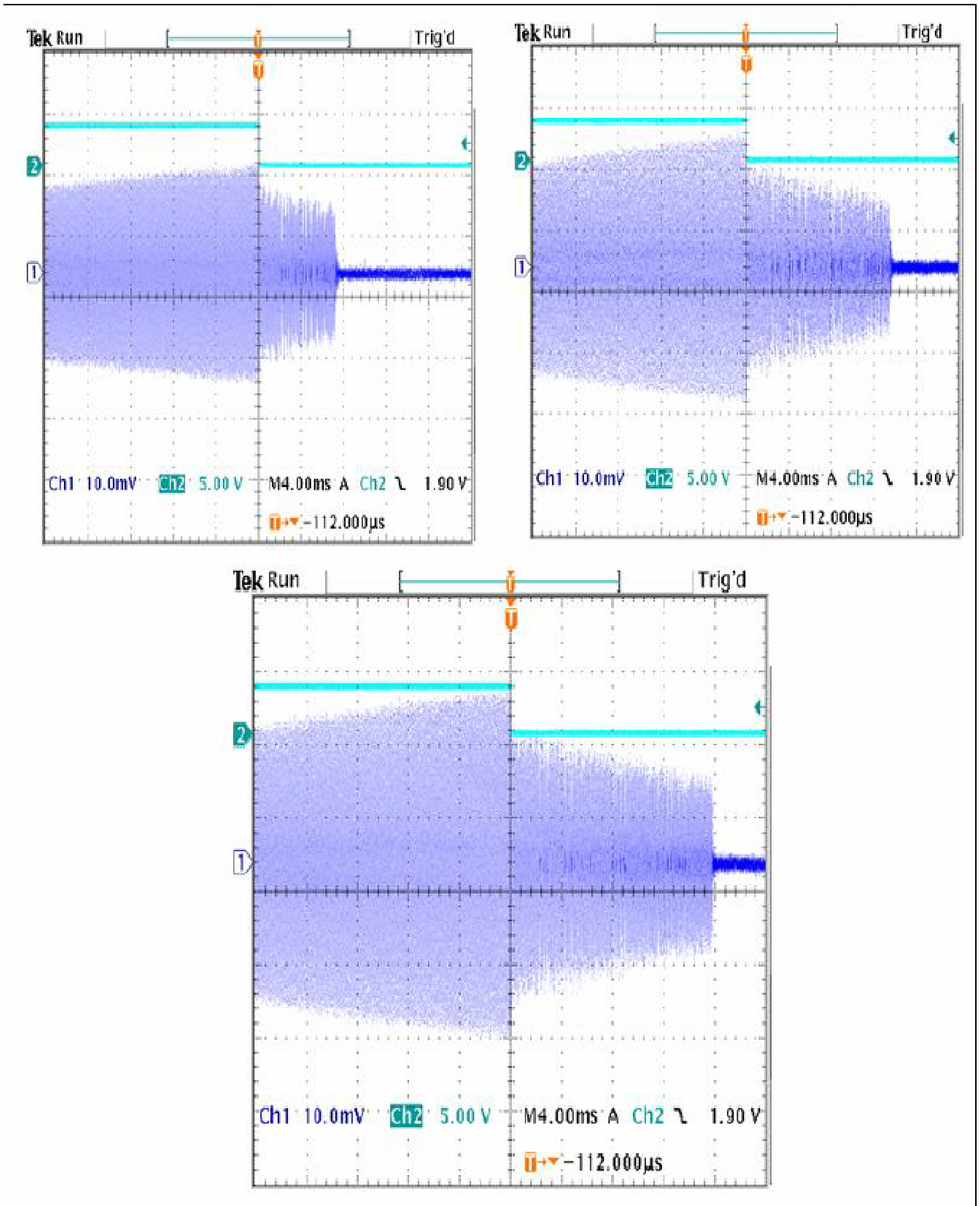
Note: Resonance frequency will have lower intervals in HDX tags compared to that of FDX tags.

4. Remove the current tag from atop the coil on the probe and return the amplitude and frequency to their starting points as mentioned in steps 3-8 of ***HDX Function Generator Setup***.
5. Continuing testing HDX tags using this setup feature.

Tag Testing Procedures

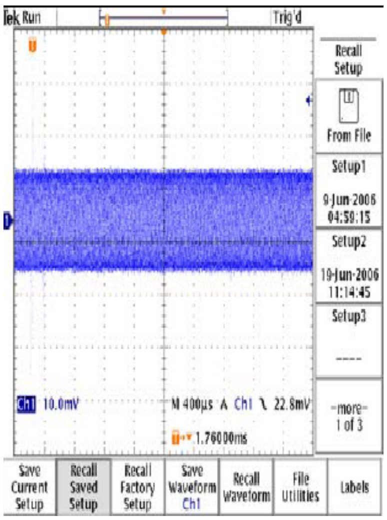
1. Begin testing by conducting the standard test on the eight FDX tags as mentioned in ***FDX Tag Reading and Recording***
2. Conduct tests on different FDX tag types in the order of Allflex-FDX, Destron, Farnam, Temple, and Y-Tex in that order following each standard test. Conduct the run of all six tag types six times.
3. Following all six runs of the different tag types, conduct the standard test on the two HDX tags.
4. When testing pedigree tags, one person will randomly select tag and place on antenna out of sight of the tester such that determination of voltage response and resonance frequencies are completed without knowledge of tag type being tested.

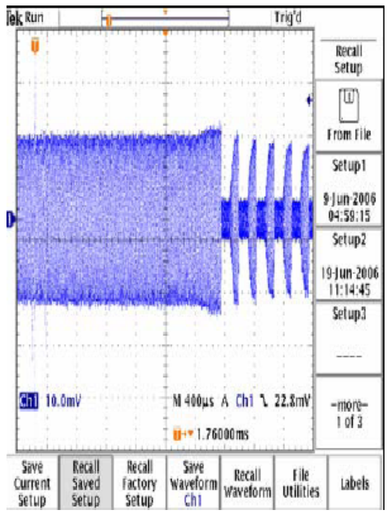
Example of half-duplex tag activation during testing for resonance frequency and voltage response

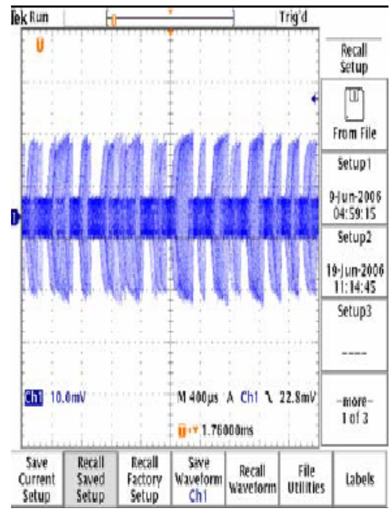


Examples of activation of two different types of full-duplex tags during testing for resonance frequency and voltage response

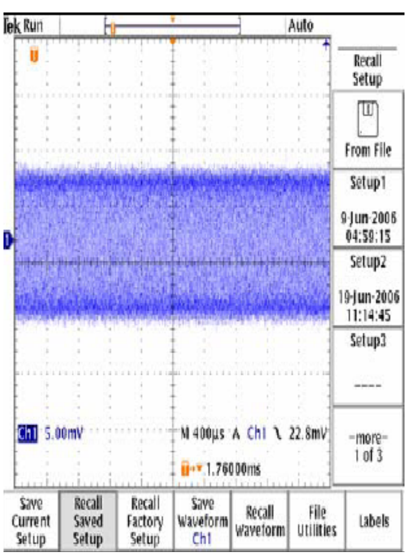
OFF **INITIATING** **ACTIVATED**

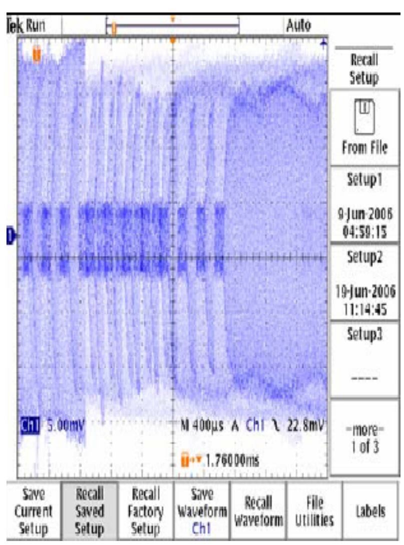


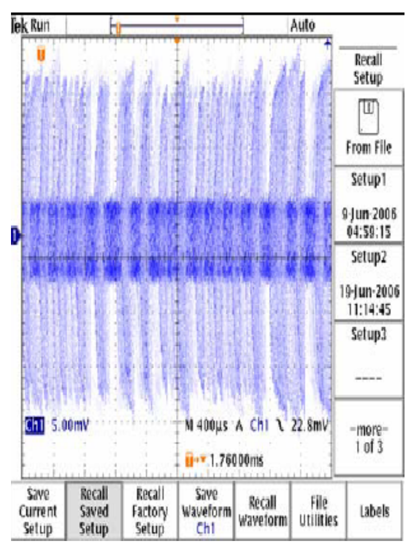




OFF **INITIATING**







Appendix C - Protocol for evaluation of potential electromagnetic interference at livestock auction markets, feedlots and cattle abattoirs

Procedure for Sale Barn Visits with the Spectrum Analyzer

Plan to arrive at facility at least ½ hour prior to first run (2 hours at unloading site).
Upon arrival find contact person(s):

Introduce yourself and others in group

Ask if they have time to please visit with you each of the 3 sites (unloading, immediately outside exit gate of sale ring, and loading) at which the SA will be set up. At this time determine if an appropriate power source is available, access to area in which the SA can be set-up while not disrupting the flow of livestock, and any other potential hindrances to data collection.

** If a significant problem arises with any area assign one group member to trouble shoot and contact either Dr. Dale Blasi or Dr. Karol Fike or Mr. Bryan Rickard.

Once you have made an initial observation of each place begin setting up the SA in the unloading area.
Follow the steps outlined on the following pages – "Quick How-To Guide for the Spectrum Analyzer" and "Livestock Auction Markets"

To move the SA to a new location be sure you have saved the data, **even if no significant events have occurred**. Need to indicate time and location where SA was when data was saved so that it is apparent by reading the file name and is also recorded in the data book. After the data has been saved, turn off the front power button and wait until the "normal" Microsoft Windows shut-down has occurred. Then turn off the power button on the back. At this point it is ok to unhook the antenna and power source.
Once the SA is ready to be moved either leave it on the cart with one hand on the handle of the SA and one hand pushing the cart, OR remove the SA from the cart and carry it carefully to the next location. DO NOT set the SA on any surface other than the cart or in the car.

** **Be sure to note start and end times at each location in the data booklet as well as the time(s) of any significant events, when you capture the data on those events record it as well.**

Once at the next location follow the Set-up steps again, be sure to record peaks when running SA with Spectrogram. At this time it is not important to allow for a warm-up time or to perform the functional and calibration checks.

After observations have been made at each of the three locations and you are preparing to leave be sure to find the contact person and thank them for allowing us to visit.

If you observed a significant event at any of the locations please inform the contact person that we may need to come visit again. This would be on a non-sale day so that we can see if the event is still occurring and turn on and off some of the electric devices.

** If you have problems with the SA please contact Sarah Ryan.

Quick How-To Guide for the Spectrum Analyzer

Initial Set-up

Assemble antenna stand
Attach antenna to Spectrum Analyzer (SA)
Attach external mouse and thumb drive to USB ports.
Plug SA into **GROUNDED** circuit
Apply power at switch on rear of unit
Apply power at switch on front of unit
Once the machine is running the desired program will automatically load onto the screen.
At the beginning of the day perform the functional test (pg. 1-14 of manual)

1. Press the **S/A** key on the front panel and then press the **Spectrum Analyzer** side key.
2. Press the **PRESET** key on the front panel to reset the analyzer.
3. Press the **INPUT** key on the front panel.
4. Press the **Signal Input Port…** side key to select **Cal**.
   The spectrum of the calibration signal appears.
5. Check that "INPUT: CAL" and "FREE RUN" are displayed in the status indicator at the upper right of the screen.

Next perform the Calibration (pg. 1-21 of manual).

1. Press the **CAL** key on the front panel.
2. Press the **Calibrate All** side key. A solid blue line at the top of the screen and moving to the right indicates process of calibration, this should only take 10 – 20 seconds.

Allow the SA to "warm-up" for 15-30 minutes prior to recording any data.

At each location perform a preliminary check with the SA on **SA with Spectrogram** to note any initial below trigger level readings. Record any significant peaks in the data booklet.

To run SA with trigger setting:

1. Press **LOAD** front key.
2. Press **LOAD STATE** side key
3. Press **LOAD STATE A** side key
4. Press **TRIG** front key.
5. Press **PAGE 2** side key
6. Press **TRIG SAVE** side key to assure the data will save automatically.

Check that Frequency is 134.2 kHz and Span is 50 kHz, as indicated on upper left of display. This is supposed to be automatic when Sate A is loaded.

Make observations (watch the screen) for any significant events, if observed record time and data (at the end of the session).

<u>At the end of each session save the data, even if nothing has occurred. See below.</u>

Saving Information

There are two ways to save information: 1. Save information to be able to bring it up on the SA screen again (as a *.iqt* file) but not export it to view anywhere else OR 2. Save information as a *.bmp* file to view on your computer but it cannot be used on the SA to analyze it. **Save one of each type.**

To save an *.iqt* file (only if data has been collected):

1. Once you capture the information push the **SAVE** front panel button.
2. Choose **SAVE TRACE** on the side key.
3. Name the file: Location and date (ex. ATCH1_JUN.10.06 for Atchison location 1 <unloading> on June 10, 2006)
4. Push **SELECT FILE** and be sure to save data in **Save Trace** folder.
5. Once appropriate file is selected press **DONE**
6. Save the file.

To save a *.bmp* file:

1. Once you capture the information push the **PRINT** front panel button.
2. Select "**Print to a File**."
3. Name the file (same as above).
4. Push **SELECT FILE** and be sure to save data in **Save Trace** folder.
5. Once appropriate file is selected press **DONE**
6. Save the file.

The *.iqt* files can be used on in the SA but may also be used to send to technical support in case of problems. Essentially, they will only be used to view previous data gathered. These files can be retrieved, viewed and saved as *.bmp* files to view on a computer. The *.bmp* files are what are needed to develop reports.

<u>Procedure for Feedlot visits with the Spectrum Analyzer</u>

Plan to arrive at feedlot 1 hour prior to beginning testing.

Be sure to save data to jump drive at the end of each visit.

<u>Initial Set-up</u>

Assemble antenna stand
Attach antenna to Spectrum Analyzer (SA)
Attach external mouse to USB ports.
Attach thumb drive to USB ports.
Plug SA into **GROUNDED** circuit
Apply power at switch on rear of unit
Apply power at switch on front of unit
Once the machine is running the desired program will automatically load onto the screen.
Note: If the program does not automatically load it can be found on the desktop.
At the beginning of the day perform the functional test (pg. 1-14 of manual)

1. Press the **S/A** key on the front panel and then press the **Spectrum Analyzer** side key.
2. Press the **PRESET** key on the front panel to reset the analyzer.
3. Press the **INPUT** key on the front panel.
4. Press the **Signal Input Port…** side key to select **Cal**.
   The spectrum of the calibration signal appears.
5. Check that "INPUT: CAL" and "FREE RUN" are displayed in the status indicator at the upper right of the screen.

Next perform the Calibration (pg. 1-21 of manual).

1. Press the **CAL** key on the front panel.
2. Press the **Calibrate All** side key. A solid blue line at the top of the screen and moving to the right indicates progress of the calibration process.
   a. This should only take 10 – 20 seconds.

Allow the SA to "warm-up" for 15-30 minutes prior to recording any data.

At each location, perform a preliminary check with the SA on **SA with Spectrogram** to note any initial below trigger level readings. Record any significant peaks in the data booklet, significant can be identified as anything greater than -115 dBm.

To run SA with trigger setting:

1. Press **LOAD** front key.
2. Press **LOAD STATE** side key
3. Press **LOAD STATE B** side key
4. Press **TRIG** front key.
5. Press **PAGE 2** side key
6. Press **TRIG SAVE and select "ON"** using side key to assure the data will save automatically.
7. Select the **TRIG SAVE** make sure it is set to **100 triggers**.

Confirm that the Frequency is 134.2 kHz and Span is 50 kHz, as indicated on upper left of display. This is supposed to be automatic when Sate B is loaded.

Note: If the Frequency and Span are not correct, use the buttons on the front panel to call up those parameters and adjust accordingly. Adjustment can be made by either typing in the correct information or using the dial on the front.

Make observations (watch the screen) for any significant events, if observed record time and data (at the end of the session).

<u>At the end of each session save the data; if nothing has occurred make a note in data book. See "Saving Information"</u>

Upon completion of setup:

1. Save a *.bmp* file of what has been recorded during warm up.
2. If anything other than "normal" write down peaks and other observations from the screen in data booklet.
    a. To identify peaks:
        i. Select the **PEAK** button on the front panel
        ii. Use the arrow buttons on either side of the peak button to select the desired peaks.
    b. If the observation is not a peak but something else different than "normal" identify as completely as possible.
3. After a *.bmp* file has been saved, start a **State B** trigger setting.

"State B" trigger setting:

1. Set up **State B** trigger using the instructions outlined above.
2. Run this setting for 1 hour.
3. After 1 hour save the trigger to the My Documents folder.
    a. To save: Press the **Save** key on the front panel.
    b. Select the correct file
    c. Name the file as identified in "Saving information"
4. Be sure to record the file name and any notes in the data booklet.

Run a "free run" for 5 minutes.

1. Press the **S/A** front panel button, in the blue box.
2. Choose **SA WITH SPECTROGRAM** on the side key.
3. The split screen should appear.
    a. If the split screen does not appear try the same steps again
    b. Or: press **Load** on the front panel, choose **Load State** then choose **State A**, this should take you back to the State A trigger setting and then try to load the SA with Spectrogram again.
4. Run this for 5 minutes.
5. Save a ***.bmp*** file.
    a. Be sure to select the folder for the appropriate plant.

Run a **State B** trigger setting for 1 additional hour.

Be sure to start and stop testing with a screen capture of the free run.

After the data has been saved, turn off the front power button and wait until the "normal" Microsoft Windows shut-down has occurred. Then turn off the power button on the back. At this point it is ok to unhook the antenna and power source.

<u>Location of SA in Feedlot</u>

The SA antenna should be placed on the stand in the horizontal position. The cord is quite long so it should not be a problem to move the antenna into an ideal location while having the analyzer out-of-the-way.

"Sniffing" Notes:

During either the beginning Free Run or ending Free Run at each location use the antenna of the SA to "sniff" out the area. Be sure to check lights, equipment being used (ex. squeeze chute, refrigerators, heaters/AC) and other areas not tested by antenna location for testing.

- In processing barn/location:
  - Arrive and begin running analyzer prior to processing crew starting.
  - Run "free run"
    - If no significant noise (> -90 dBm):
      - Record observations of noises that maybe occurring below -90dBm level.
    - If significant noises (> -90 dBm)
      - Record observations of those noises above -90dBm level.
    - Save a .bmp of "free run"
  - Processing crew should have started or be starting:
  - Run 1 hour of State B – Trigger setting
    - If triggers recorded save data (.iqt) and save .bmp
    - If no triggers make a note in data book
  - Run 5 minutes of "free run"
    - Record significant noises, if any.
    - If triggers received, attempt to locate the source of the noise that caused the trigger
    - Save a .bmp of "free run"
  - Run 1 hour of State B – Trigger setting
    - See previous
  - Run 5 minutes of "free run"
    - See previous
  - If noises were observed, run an additional hour during a time when processing crew is **not** working

- At load/unload (repeat at each location)
  - Run 5 minutes of "free run"

        - Record observations of noises that maybe occurring below or above -90dBm level.
        - Save a .bmp of "free run"
    - Run 1 hour of State B – Trigger setting
        - If triggers recorded save data (.iqt) and save .bmp
        - If no triggers make a note in data book
    - Run 5 minutes of "free run"
        - Record significant noises, if any.
        - If triggers received, attempt to locate the source of the noise that caused the trigger
        - Save a .bmp of "free run"
    - Run 1 hour of State B – Trigger setting
        - See previous
    - Run 5 minutes of "free run"
        - See previous

Saving Information

There are two ways to save information:
1. Save information to be able to bring it up on the SA screen again (as a *.iqt* file) but not export it to view anywhere else
2. Save information as a *.bmp* file to view on your computer but it cannot be used on the SA to analyze it. **Save one of each type.**

Trigger Only:To save an *.iqt* file (only if data has been collected):

7. Once you capture the information push the **SAVE** front panel button.
8. Choose **SAVE DATA** on the side key.
9. Name the file: Location and number (GBF_1.iqt for Great Bend Feeding, location/save #1)
10. Push **SELECT FILE** and be sure to save data in **My Documents folder.**
11. Once appropriate file is selected press **DONE**
12. Save the file.

Trigger and Free Run: **To save a *.bmp* file**:

7. Once you capture the information push the **PRINT** front panel button.
8. Select "**Print to a File**."
9. Name the file in similar fashion to the process in Step #3 of the previous "To save an *.iqt* file" instructions.
10. Push **SELECT FILE** and be sure to save data in **My Documents**.
11. Once appropriate file is selected press **DONE**
12. Save the file.

Quick How-To Guide for the Spectrum Analyzer – Packing Plant Visits

Plan to arrive at plant at least 1 to 1½ hours prior to starting testing. This is somewhat plant dependent.

Be sure to save data to jump drive at the end of each testing period/run.

Initial Set-up

Assemble antenna stand
Attach antenna to Spectrum Analyzer (SA)
Attach external mouse to USB ports.
Attach thumb drive to USB ports.
Plug SA into **GROUNDED** circuit
Apply power at switch on rear of unit
Apply power at switch on front of unit
Once the machine is running the desired program will automatically load onto the screen.
Note: If the program does not automatically load it can be found on the desktop.
At the beginning of the day perform the functional test (pg. 1-14 of manual)

1. Press the **S/A** key on the front panel and then press the **Spectrum Analyzer** side key.
2. Press the **PRESET** key on the front panel to reset the analyzer.
3. Press the **INPUT** key on the front panel.
4. Press the **Signal Input Port…** side key to select **Cal**.
   The spectrum of the calibration signal appears.
5. Check that "INPUT: CAL" and "FREE RUN" are displayed in the status indicator at the upper right of the screen.

Next perform the Calibration (pg. 1-21 of manual).

1. Press the **CAL** key on the front panel.
2. Press the **Calibrate All** side key. A solid blue line at the top of the screen and moving to the right indicates progress of the calibration process.
   b. This should only take 10 – 20 seconds.

Allow the SA to "warm-up" for 15-30 minutes prior to recording any data.

At each location, perform a preliminary check with the SA on **SA with Spectrogram** to note any initial below trigger level readings. Record any significant peaks in the data booklet, significant can be identified as anything greater than -110 dBm.

To run SA with trigger setting:

1. Press **LOAD** front key.
2. Press **LOAD STATE** side key
3. Press **LOAD STATE B** side key
4. Press **TRIG** front key.
5. Press **PAGE 2** side key
6. Press **TRIG SAVE and select "ON"** using side key to assure the data will save automatically.
7. Select the **TRIG SAVE** make sure it is set to **200 triggers**.

Confirm that the Frequency is 134.2 kHz and Span is 50 kHz, as indicated on upper left of display. This is supposed to be automatic when Sate B is loaded.

Note: If the Frequency and Span are not correct use the buttons on the front panel to call up those parameters and adjust accordingly. Adjustment can be made by either typing in the correct information or using the dial on the front.

Make observations (watch the screen) for any significant events, if observed record time and data (at the end of the session).

<u>At the end of each session save the data, even if nothing has occurred. See below.</u>

<u>Saving Information</u>

There are two ways to save information: 1. Save information to be able to bring it up on the SA screen again (as a *.iqt* file) but not export it to view anywhere else OR 2. Save information as a *.bmp* file to view on your computer but it cannot be used on the SA to analyze it. **Save one of each type.**

The folders for each plant are already available in the "My Documents" folder, just select the appropriate folder for the plant.

Trigger Only:To save an *.iqt* file (only if data has been collected):

1. Once you capture the information push the **SAVE** front panel button.
2. Choose **SAVE DATA** on the side key.
3. Name the file: Location and date (ex. TY_EM_7_10_07_1.iqt for Tyson in Emporia first save on July 10, 2007)
4. Push **SELECT FILE** and be sure to save data in **Save Trace** folder and the **folder for the specific plant**.
5. Once appropriate file is selected press **DONE**
6. Save the file.

Trigger and Free Run: **To save a *.bmp* file**:

1. Once you capture the information push the **PRINT** front panel button.
2. Select "**Print to a File**."
3. Name the file in similar fashion to the process in Step #3 of the previous "To save an *.iqt* file" instructions.

4. Push **SELECT FILE** and be sure to save data in **Save Trace** folder and the **folder for the specific plant**.
5. Once appropriate file is selected press **DONE**
6. Save the file.

The *.iqt* files can be used on in the SA but may also be used to send to technical support in case of problems. Essentially, they will only be used to view previous data gathered. These files can be retrieved, viewed and saved as *.bmp* files to view on a computer. The *.bmp* files are what are needed to develop reports.

Upon completion of setup:

1. Save a *.bmp* file of what has been recorded during warm up.
2. If anything other than "normal" write down peaks and other observations from the screen in data booklet.
    a. To identify peaks:
        i. Select the **PEAK** button on the front panel
        ii. Use the arrow buttons on either side of the peak button to select the desired peaks.
    b. If the observation is not a peak but something else different than "normal" identify as completely as possible.
3. After a *.bmp* file has been saved, start a **State B** trigger setting.

"State B" trigger setting:

1. Set up **State B** trigger using the instructions outlined above.
2. Run this setting for 1 hour.
3. After 1 hour save the trigger to the file for the plant.
    a. To save: Press the **Save** key on the front panel.
    b. Select the correct file
    c. Name the file as identified in "Saving information"
4. Be sure to record the file name and any notes in the data booklet.

Run a "free run" for 5 minutes.

1. Press the **S/A** front panel button, in the blue box.
2. Choose **SA WITH SPECTROGRAM** on the side key.
3. The split screen should appear.
    b. If the split screen does not appear try the same steps again
    c. Or: press **Load** on the front panel, choose **Load State** then choose **State B**, this should take you back to the State B trigger setting and then try to load the SA with Spectrogram again.
4. Run this for 5 minutes.
5. Save an ***.iqt*** and a ***.bmp*** file.
    d. Be sure to select the folder for the appropriate plant.

Run a **State B** trigger setting.

Repeat this process for the 8 hour testing window.

Be sure to start and stop testing with a screen capture of the free run.

After the data has been saved, turn off the front power button and wait until the "normal" Microsoft Windows shut-down has occurred. Then turn off the power button on the back. At this point it is ok to unhook the antenna and power source.

If Free Run screen won't load:

1. Press **Load**.
2. Press **Load State**
3. Press **State A**
4. Wait for "ready" to show in right hand portion of screen.
5. Press **SA**
6. Press **SA w/ Spectrogram**

Location of SA in Plant

Depending on plant, the equipment (or antenna at least) should be as close to the actual site where tags would be read as possible.

The SA antenna should be placed on the stand in the horizontal position. The cord is quite long so it should not be a problem to move the antenna into an ideal location while having the analyzer out-of-the-way.

Orientation Notes:

Primary Orientation: The SA antenna faces the same direction as the EID tag reader, as if the SA antenna was reading the EID tags.

Opposite Orientation: The SA antenna faces the opposite direction of the EID tag reader, away from the ears and chain.

Right Orientation: The SA antenna faces to the right from the primary position, depending on the plant this may be with or against the flow of the chain.

Left Orientation: The SA antenna faces to the left from the primary position, depending on the plant this may be with or against the flow of the chain.

"Sniffing" Notes:

All sniffing is done in the primary orientation. If a reader is available work from the center of the reader out. If no reader is available, work from the location of the testing out. Each site should be recorded for 5 minutes of Free Run.

5 feet to the right
10 feet to the right
5 feet to the left
10 feet to the left

~ 5 feet directly behind the reader, it is acceptable to be higher off the ground than with the other testing, just be sure to note the height and exact inches away from reader/ original location.

** If equipment or plant operations prevent testing in one of the locations just omit.

** If a noticeable change occurs during sniffing, screen observations change when in a specific location, it is acceptable to use the SA antenna to observe a variety of locations.

Save a picture if a specific source of noise can be pin-pointed.

Appendix D - Reports on evaluation of KSU Beef Stocker Unit barn and modular building for electromagnetic interferences

Evaluation of KSU Beef Stocker Unit Barn for Electromagnetic Interferences (This is the location where transponder read distance and read rate analyses were conducted)

Date: June 21, 2005

To: Professor Dale Blasi, Animal Science and Industry
Annette M. Bryant, Graduate Student, Animal Science and Industry

From: Russell Taylor, EDL

Subject: RFID Radio Frequency Environment MeasurementsTaken May 12, 2005.

Introduction:

Measurements have been taken at the KSU Beef Stocker Unit barn to measure the transmission signals of low frequency and ultra high frequency (UHF) RFID systems. The intent of the measurements was to measure the power of the transmitting antenna and discover if there were noise sources in the frequency ranges measured which may affect RFID tag interrogation.

Low Frequency Measurements:

For the low frequency measurements, a HP 4396B spectrum analyzer was used to take spectrum plots. The analyzer attached to a TIRIS stick antenna part number RI-ANT-S02C-00 using a 50 foot LMR400 coaxial cable. The plots below list their measurement features in their captions. In each of these measurements the base of the transmitting antenna was 25 inches from the ground. The lowest point of the receiving stick antenna was 1m from the ground in all the low frequency measurements below. Various area electrical items were turned on and off for the measurements to see if there were any contributions to the power spectrum.

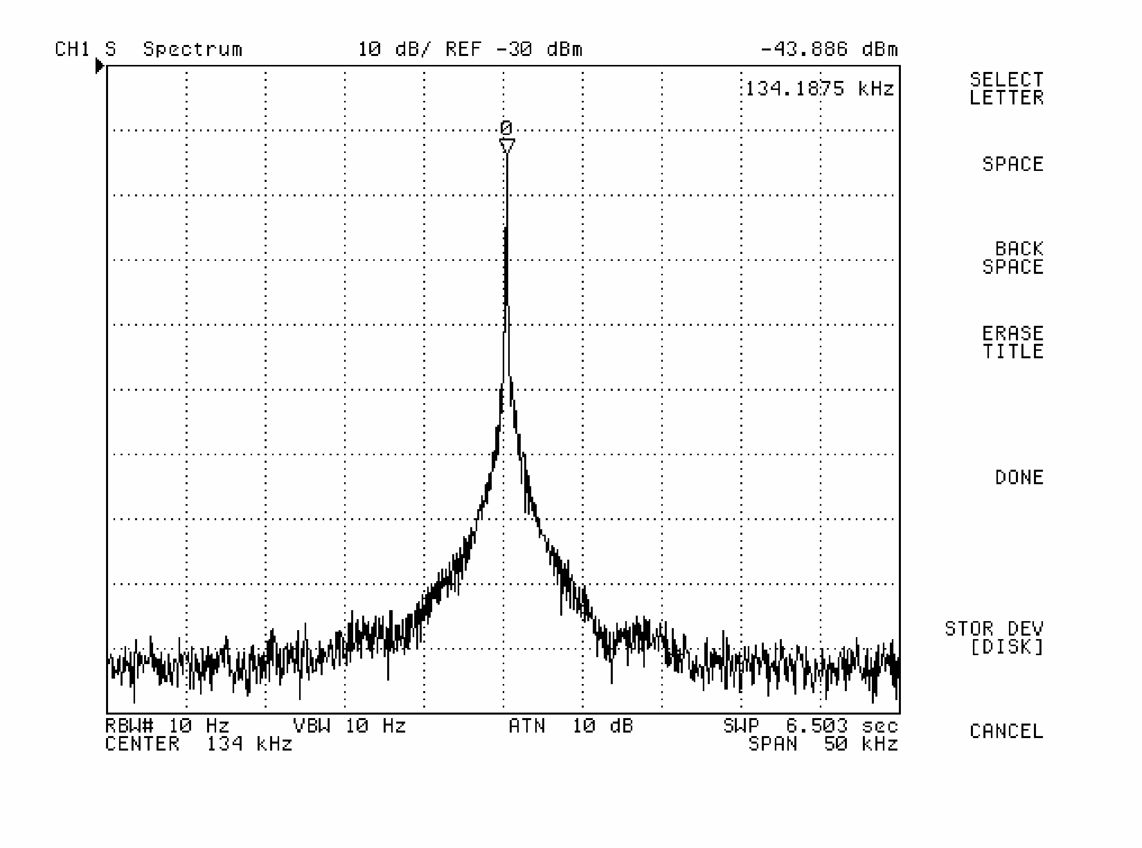


Figure 56. Stick antenna is 3 m from the transmitting antenna in a horizontal orientation perpendicular to the face of the transmitting antenna. Peak measured power of -43.886 dBm occurred at 134.1875 kHz. Room lights were turned on.

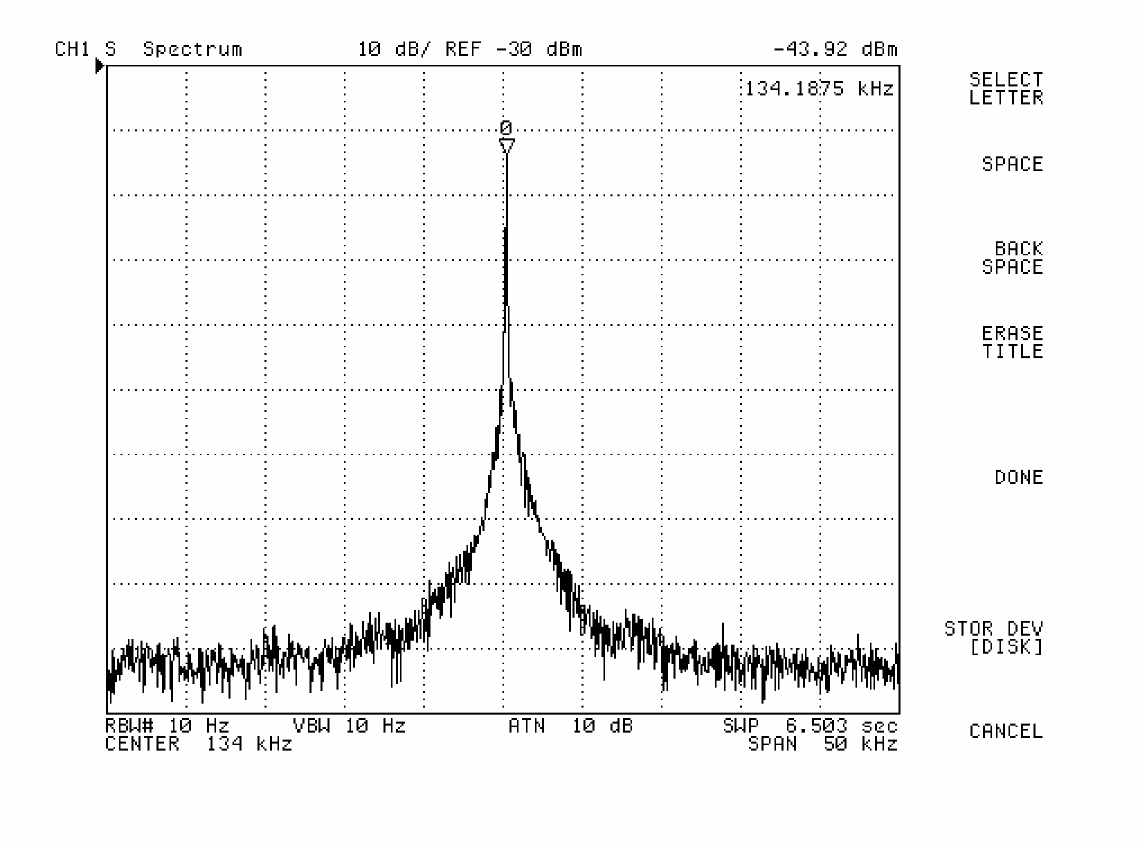


Figure 57. Repeat measurement of figure 1. Stick antenna is 3 m from the transmitting antenna in a horizontal orientation perpendicular to the face of the transmitting antenna. Peak measured power of -43.92 dBm occurred at 134.1875 kHz. Room lights were turned on.

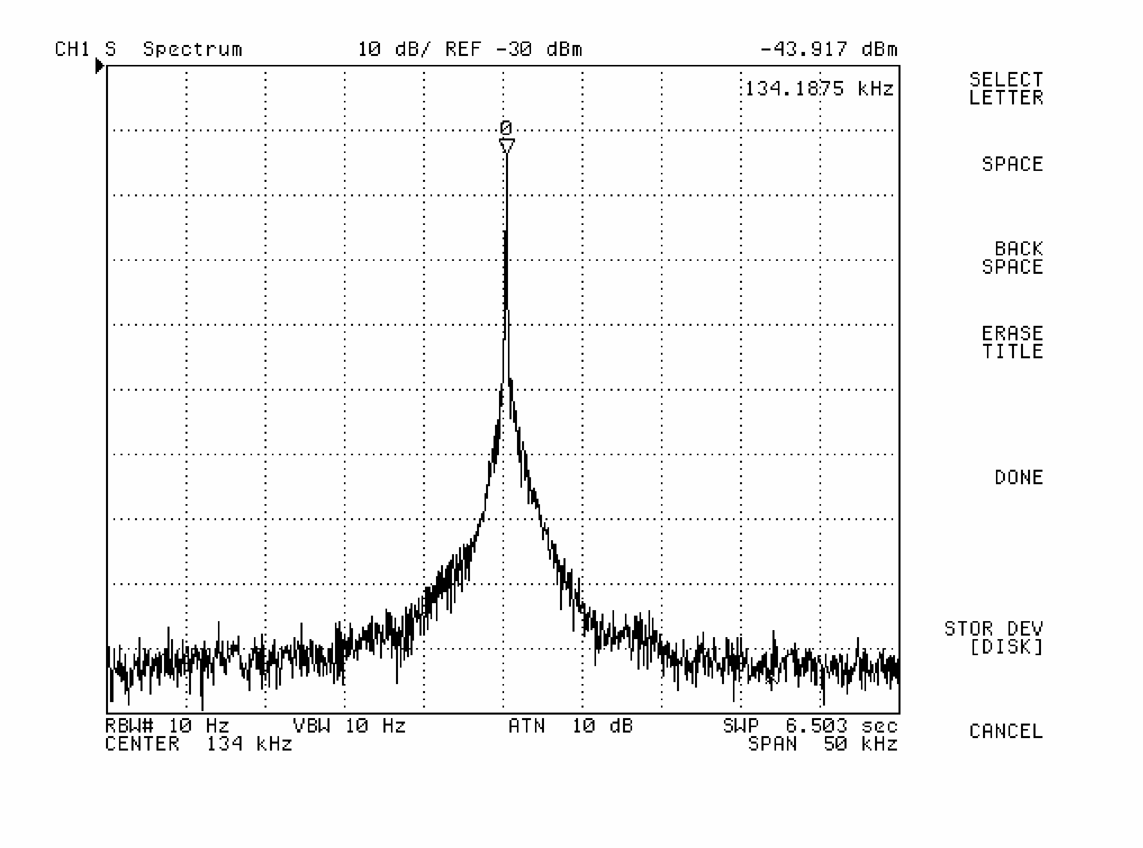


Figure 58. Repeat measurement of figures 1 and 2. Stick antenna is 3 m from the transmitting antenna in a horizontal orientation perpendicular to the face of the transmitting antenna. Peak measured power of -43.917 dBm occurred at 134.1875 kHz. Room lights were turned on.

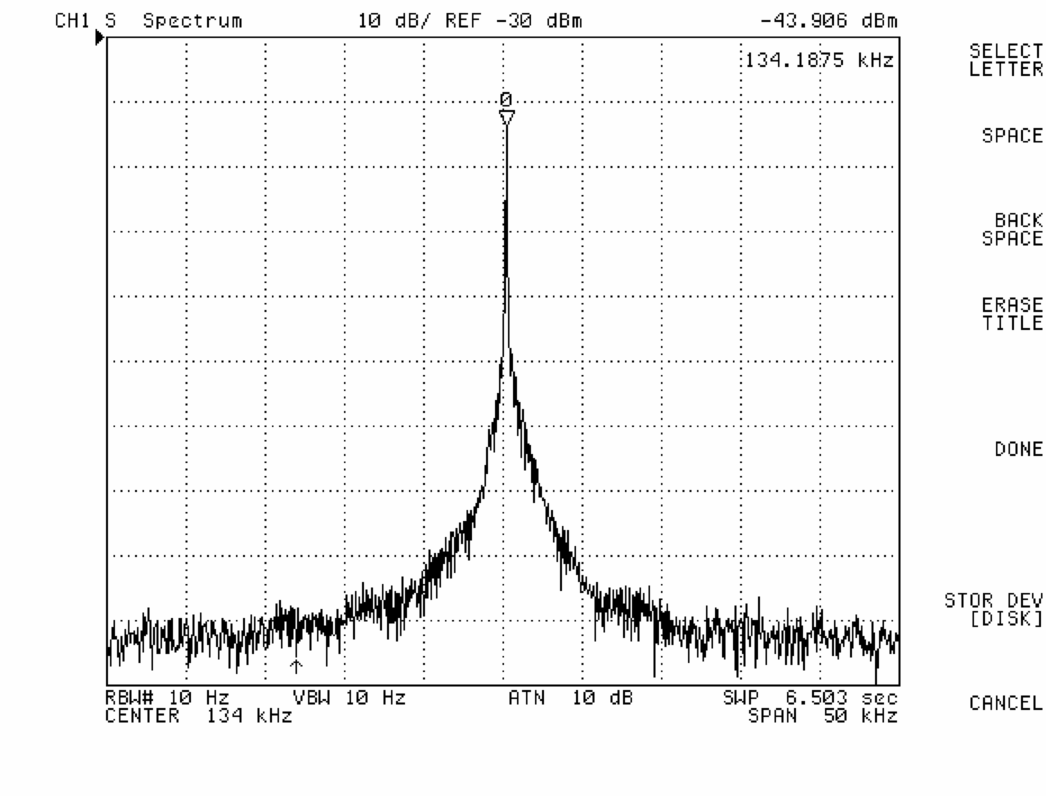


Figure 59. Stick antenna is 3 m from the transmitting antenna in a horizontal orientation perpendicular to the face of the transmitting antenna. Peak measured power of -43.906 dBm occurred at 134.1875 kHz. Room lights and air conditioner were turned on.

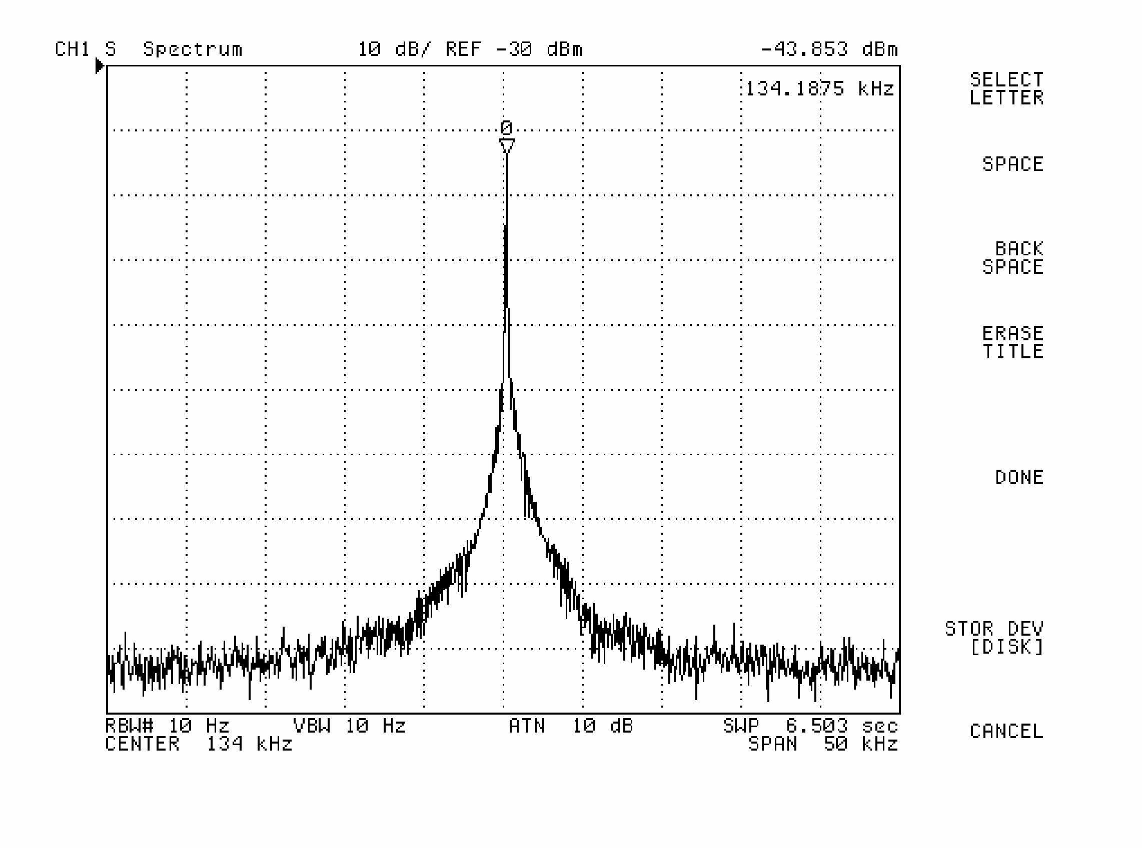


Figure 60. Stick antenna is 3 m from the transmitting antenna in a horizontal orientation perpendicular to the face of the transmitting antenna. Peak measured power of -43.853 dBm occurred at 134.1875 kHz. Room lights and chute hydraulics were turned on.

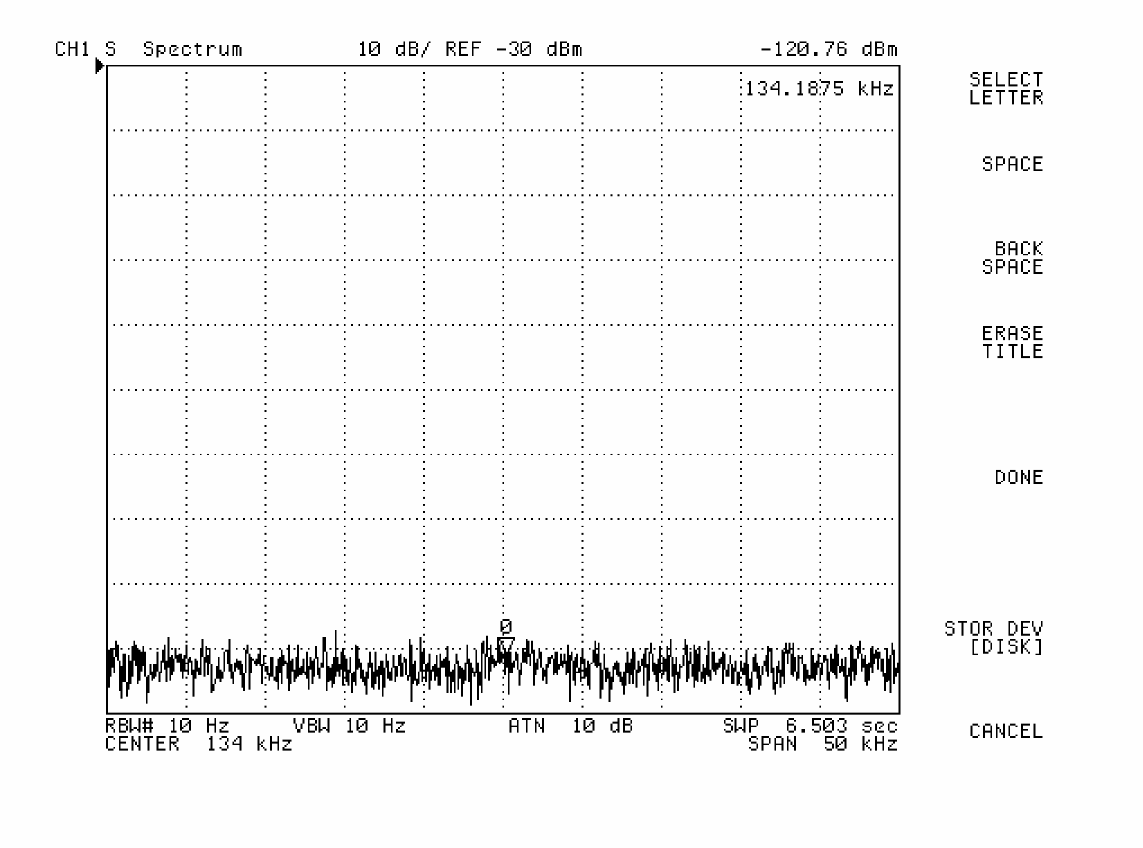


Figure 61. Stick antenna is 3 m from the transmitting antenna in a horizontal orientation perpendicular to the face of the transmitting antenna. Transmitting antenna is turned off. Room lights, air conditioner, and chute hydraulics are turned off.

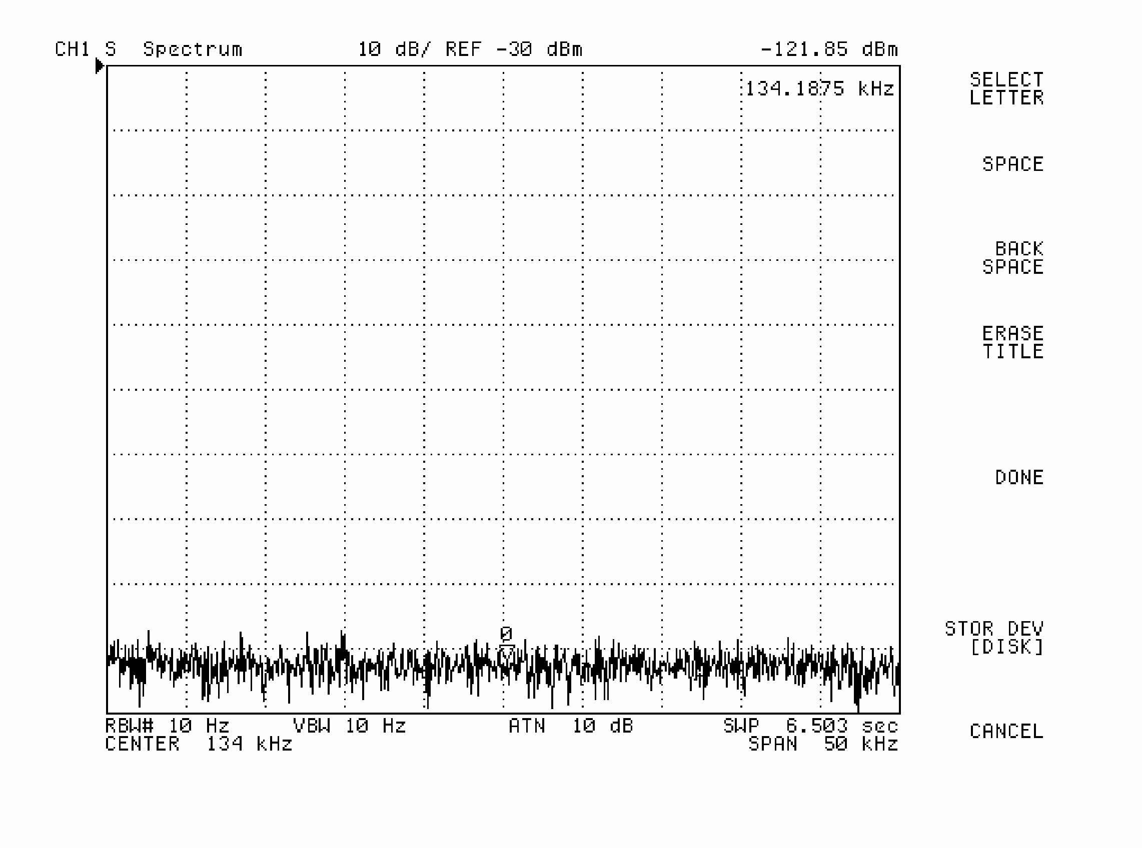


Figure 62. Stick antenna is 3 m from the transmitting antenna in a horizontal orientation perpendicular to the face of the transmitting antenna. Transmitting antenna is turned off. Room lights and air conditioner and chute hydraulics were turned on.

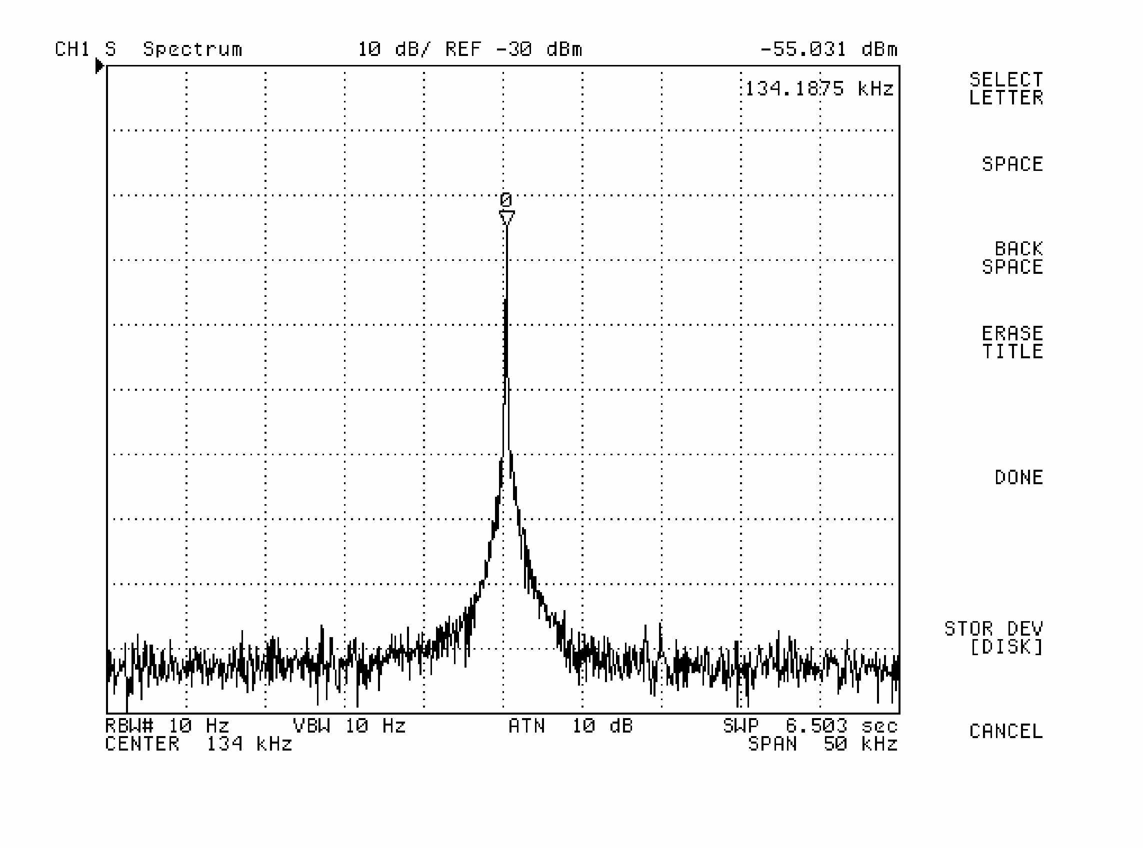


Figure 63. Stick antenna is 3 m from the transmitting antenna. Stick antenna is horizontal and parallel to the face of the transmitting antenna. Peak power of -55.031 dBm measured at 134.1875 kHz. Lights, air conditioner and chute hydraulics turned off.

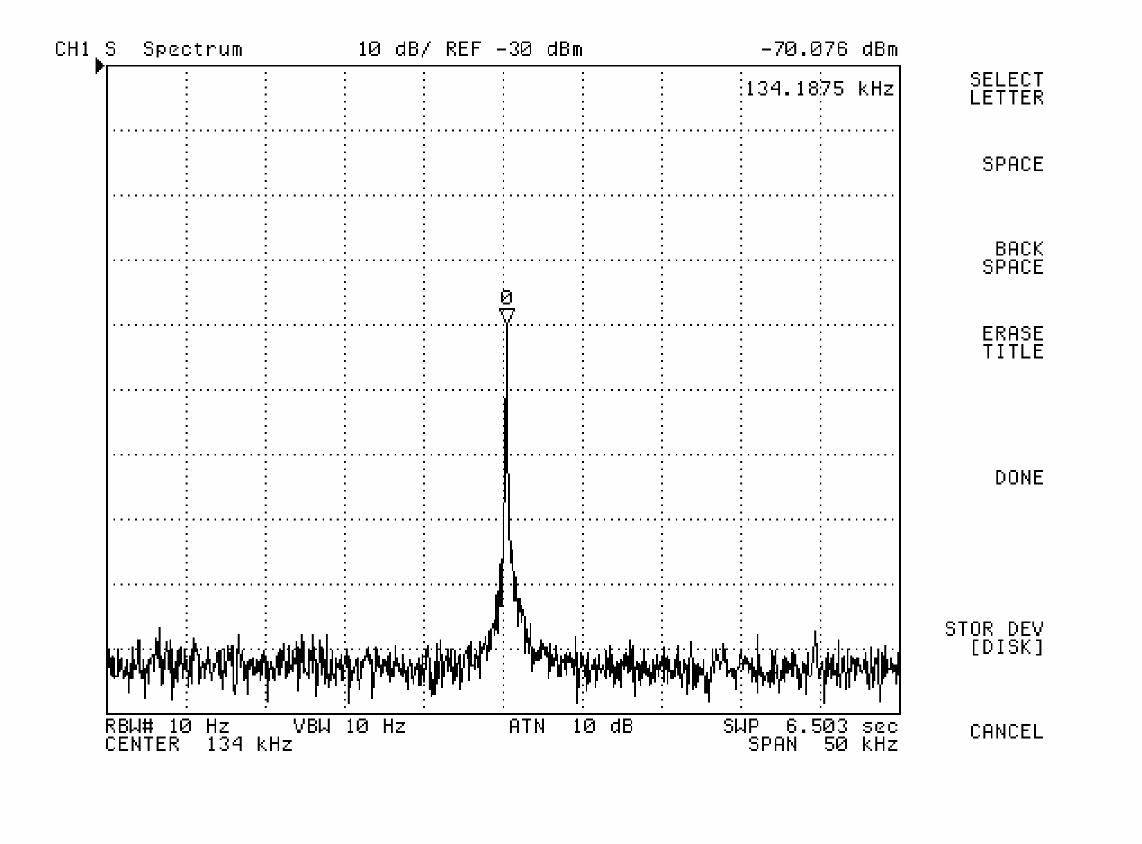


Figure 64. Stick antenna is 3 m from the transmitting antenna in a vertical orientation. Peak power at 3 m was found by manually moving the antenna away from center. Measured peak power of -70.076 dBm at 134.1875 kHz was found 8 inches left of center as looking out from the transmitting antenna. Lights, air conditioner and chute hydraulics turned off.

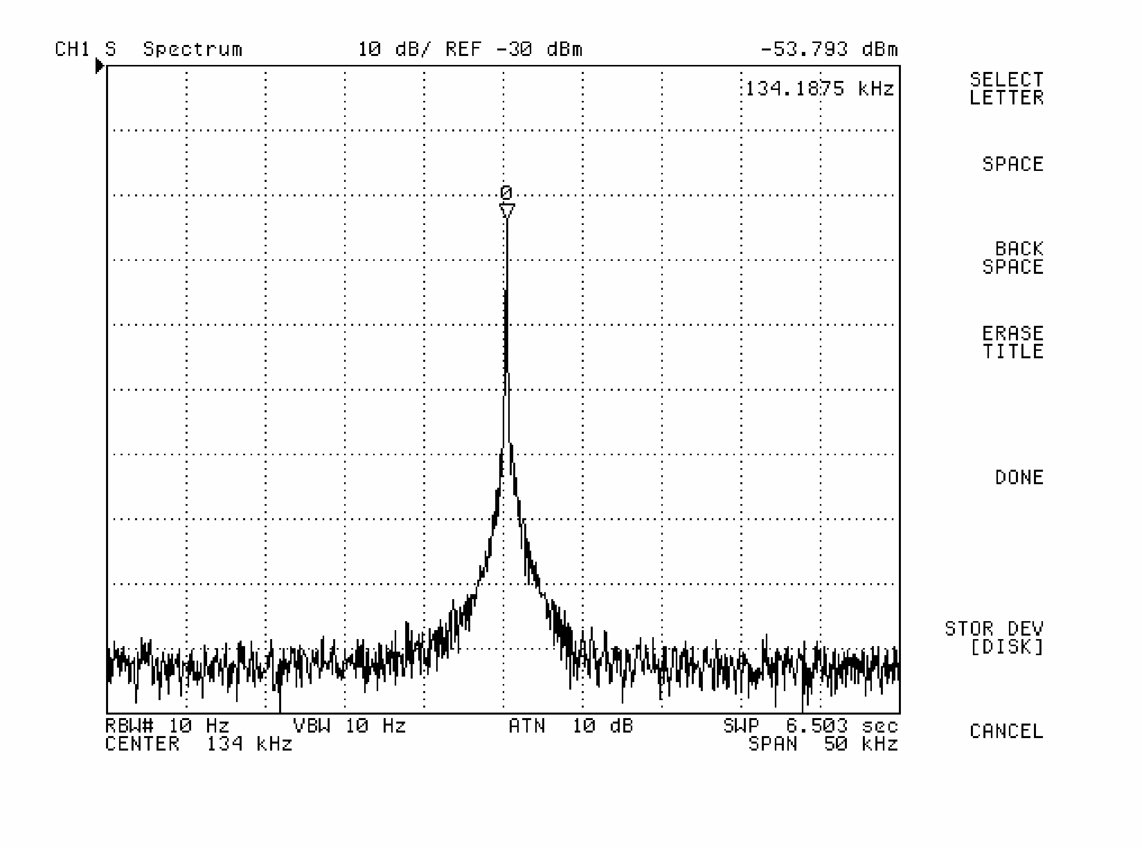


Figure 65. Stick antenna is 3 m from the transmitting antenna. Stick antenna is horizontal and parallel to the face of the transmitting antenna. Peak power at 3 m was found by manually moving the antenna away from center. Measured peak power of -53.793 dBm at 134.1875 kHz was found 9.25 inches left of center as looking out from the transmitting antenna. Lights, air conditioner and chute hydraulics turned off.

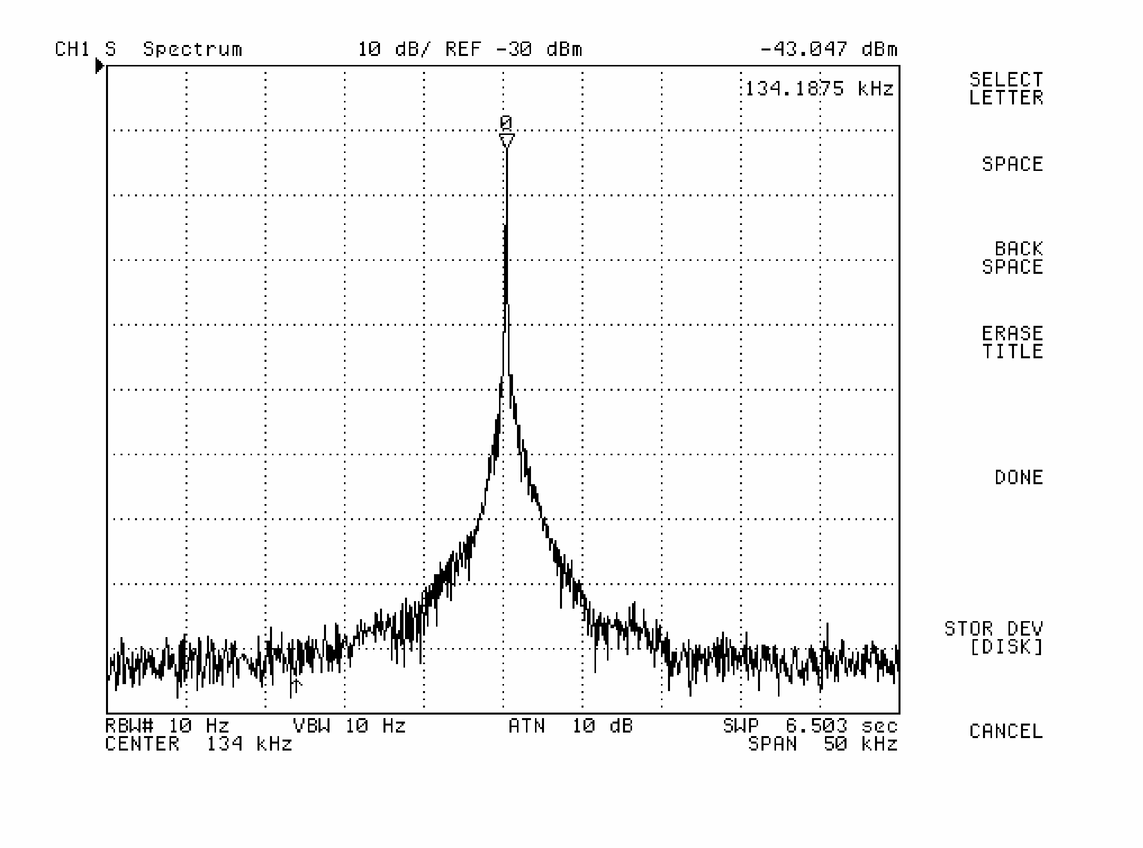


Figure 66. Stick antenna is 3 m from transmitting antenna. Stick antenna is horizontal and perpendicular to the face of the transmitting antenna. Peak power at 3 m was found by manually moving the antenna away from center. Measured peak power of -43.047 dBm at 134.1875 kHz was found 9.5 inches right of center as looking out from the transmitting antenna. Lights, air conditioner and chute hydraulics turned off.

UHF Measurements:

Ultra High Frequency measurements in the range of 900 MHz to 930 MHz were taken using the HP 4396B spectrum analyzer. The antenna used was an Astron Wireless V9180 connected to the spectrum analyzer through a 50 foot LMR400 coaxial cable. Measurement features are listed in the caption of each plot. In all the UHF measurements below, the lowest point of the Astron V9180 antenna is 1 m from the ground.

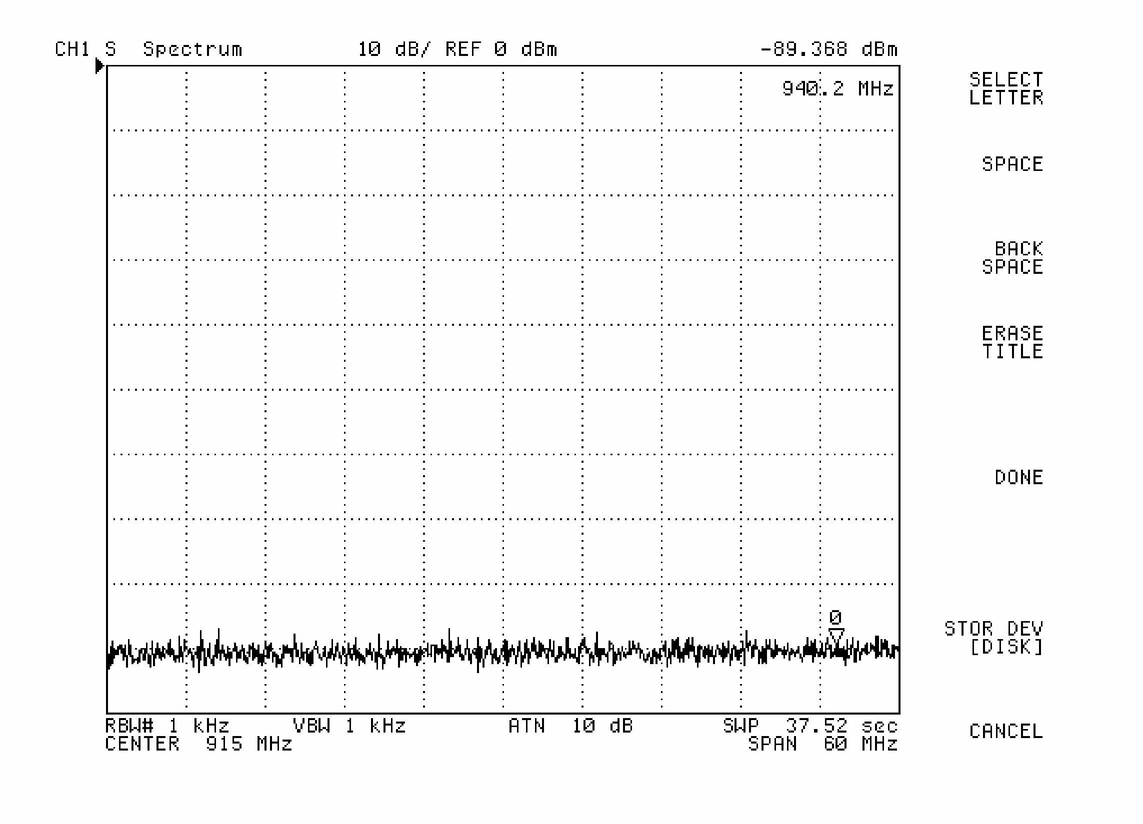


Figure 67. Astron antenna is in the vertical orientation. UHF RFID transmitting antenna turned off.

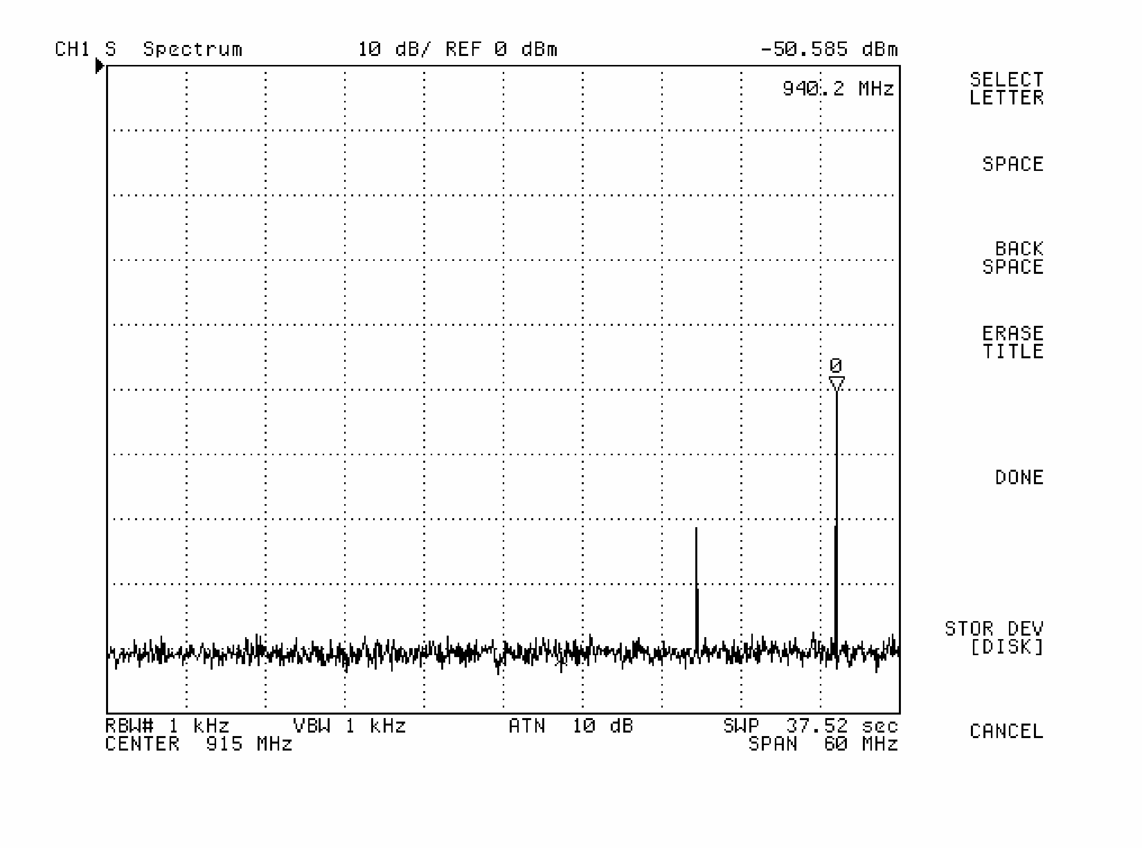


Figure 68. Repeat measurement of figure 12. Astron antenna is in the vertical orientation. UHF RFID transmitting antenna turned off. Plot shows spurious signals at 929 MHz and 940 MHz. The peak at 940 MHz is at -50.585 dBm.

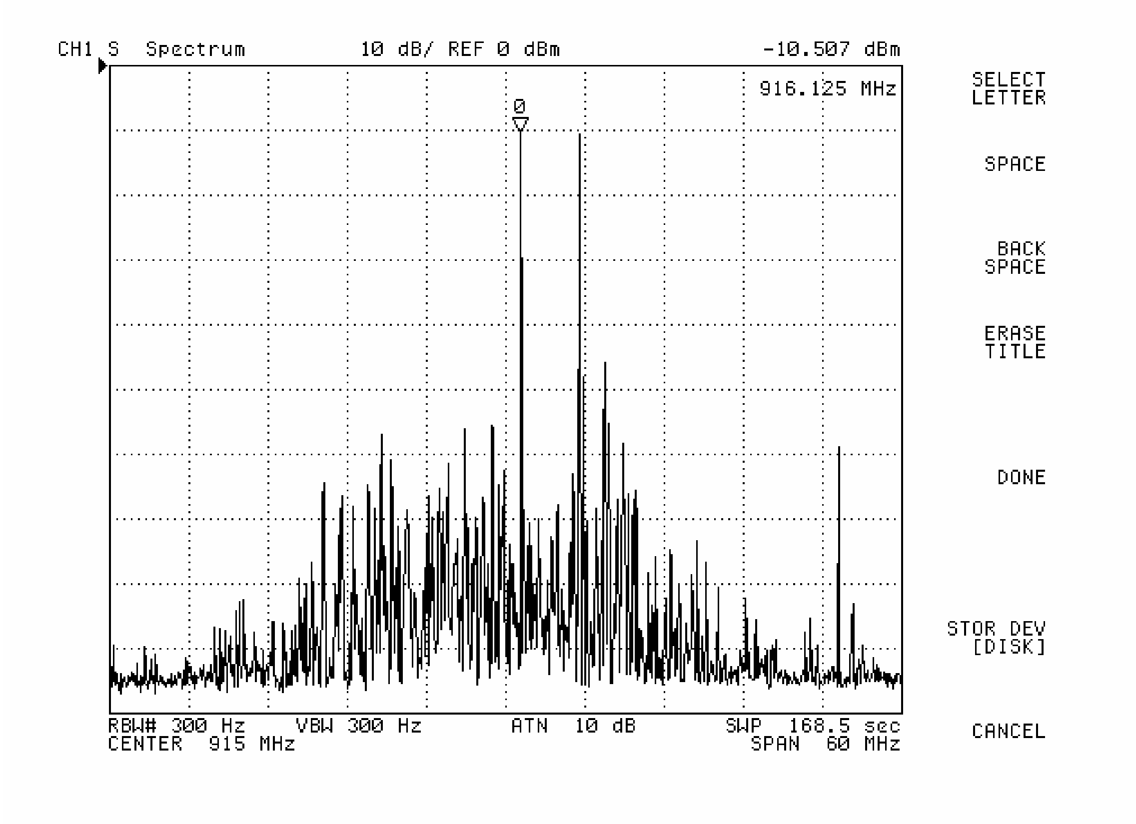


Figure 69. Astron antenna is in a vertical orientation 3 meters from the AWID transmitting antenna.

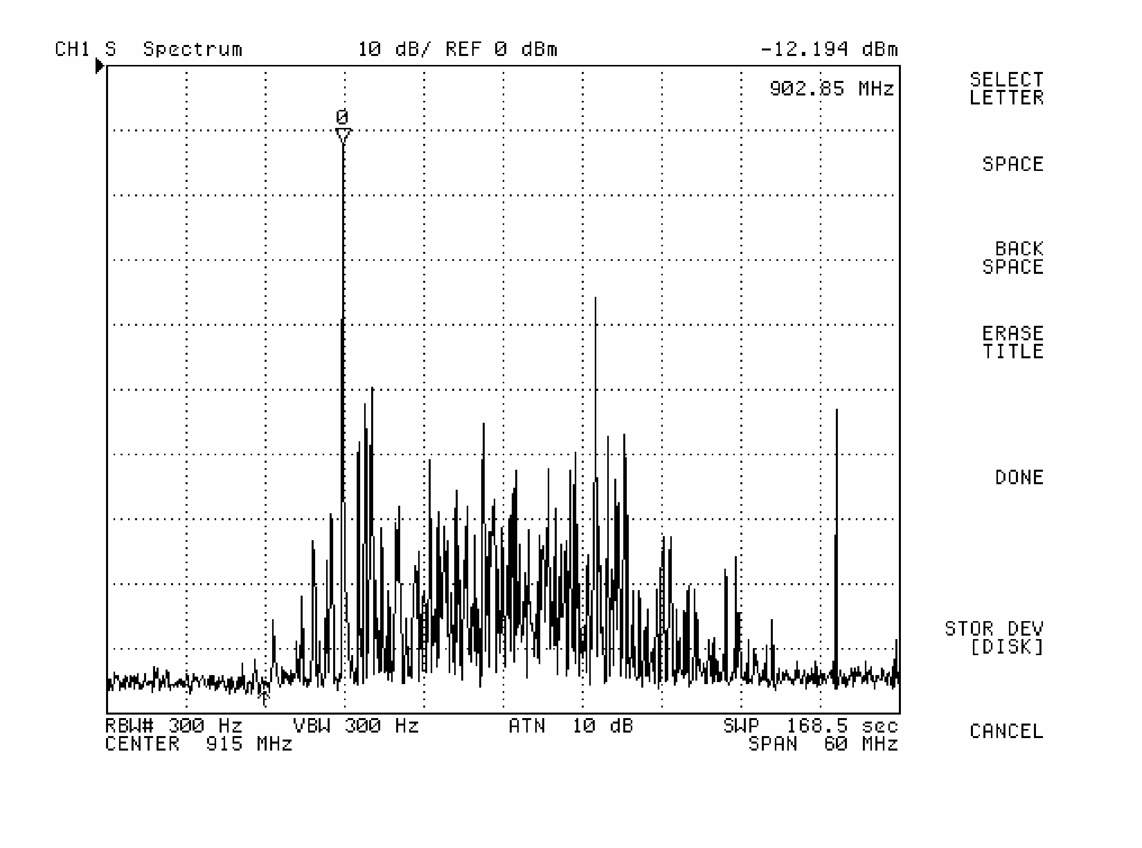


Figure 70. Handheld reader used as transmitting antenna. Astron antenna is in a vertical orientation 3 m from the handheld transmitting antenna.

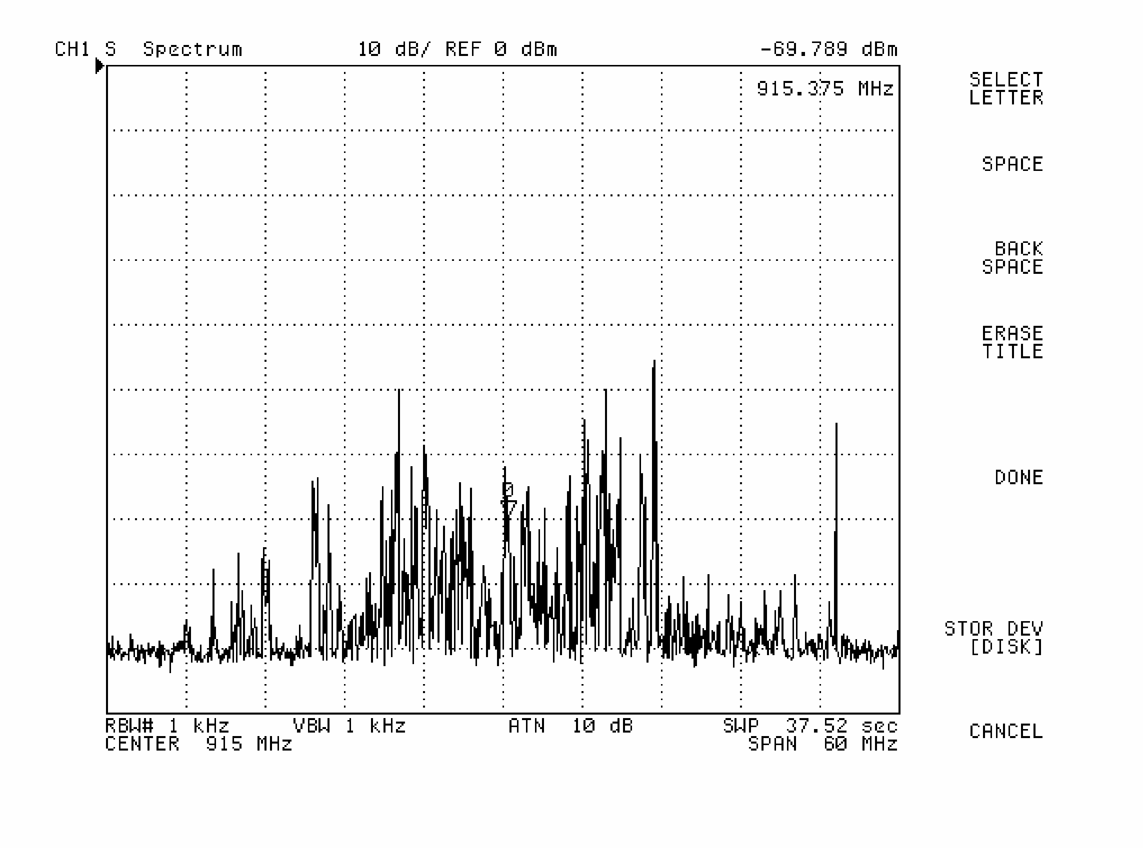


Figure 71. Astron antenna is in a vertical orientation 3 meters from the AWID transmitting antenna.

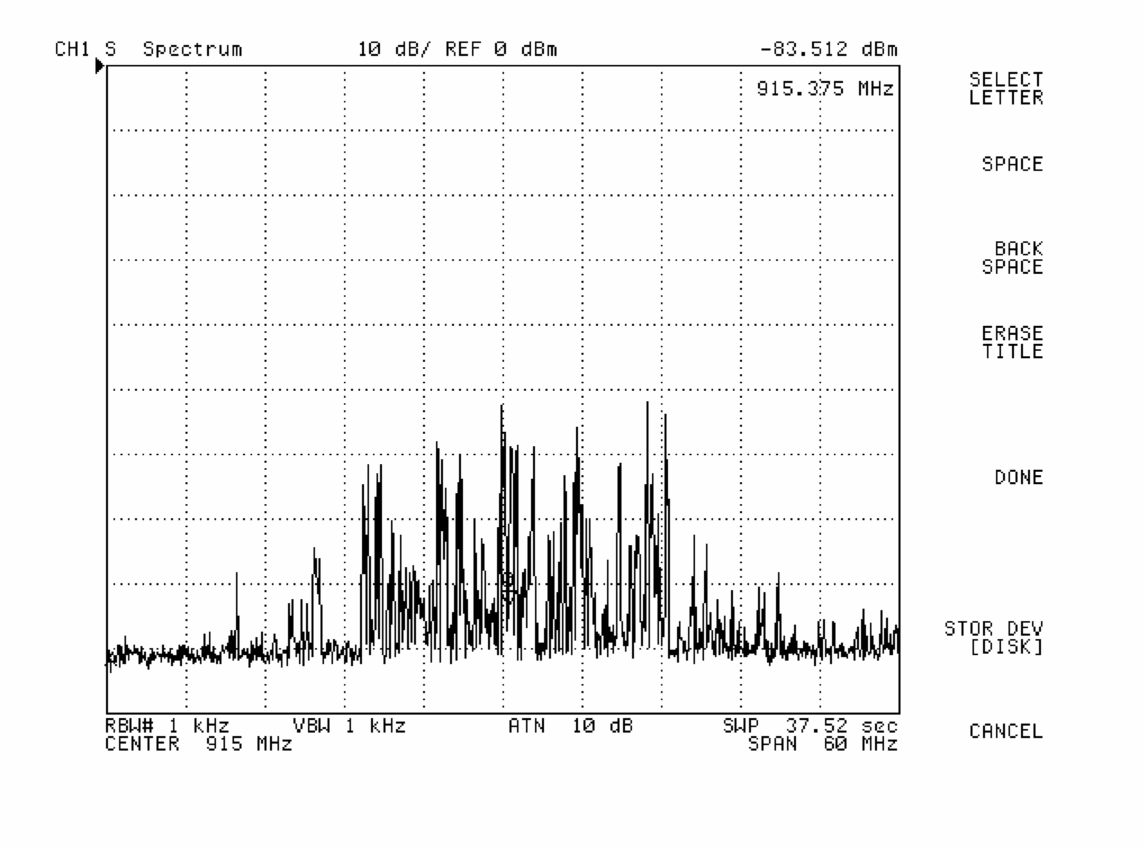


Figure 72. Repeat measurement of figure 16. Astron antenna is in a vertical orientation 3 meters from the AWID transmitting antenna.

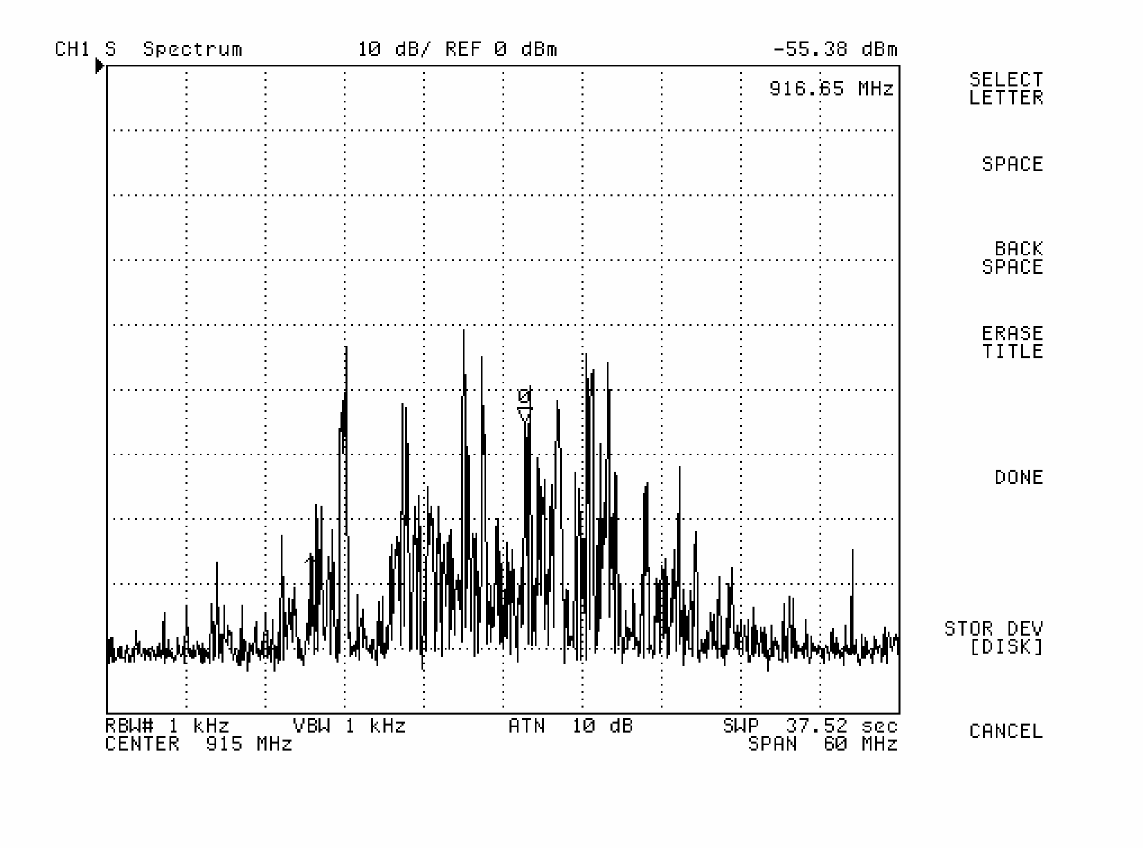


Figure 73. Astron antenna is 3 m from the transmitting antenna. The Astron antenna is in a horizontal orientation parallel to the face of the transmitting AWID antenna.

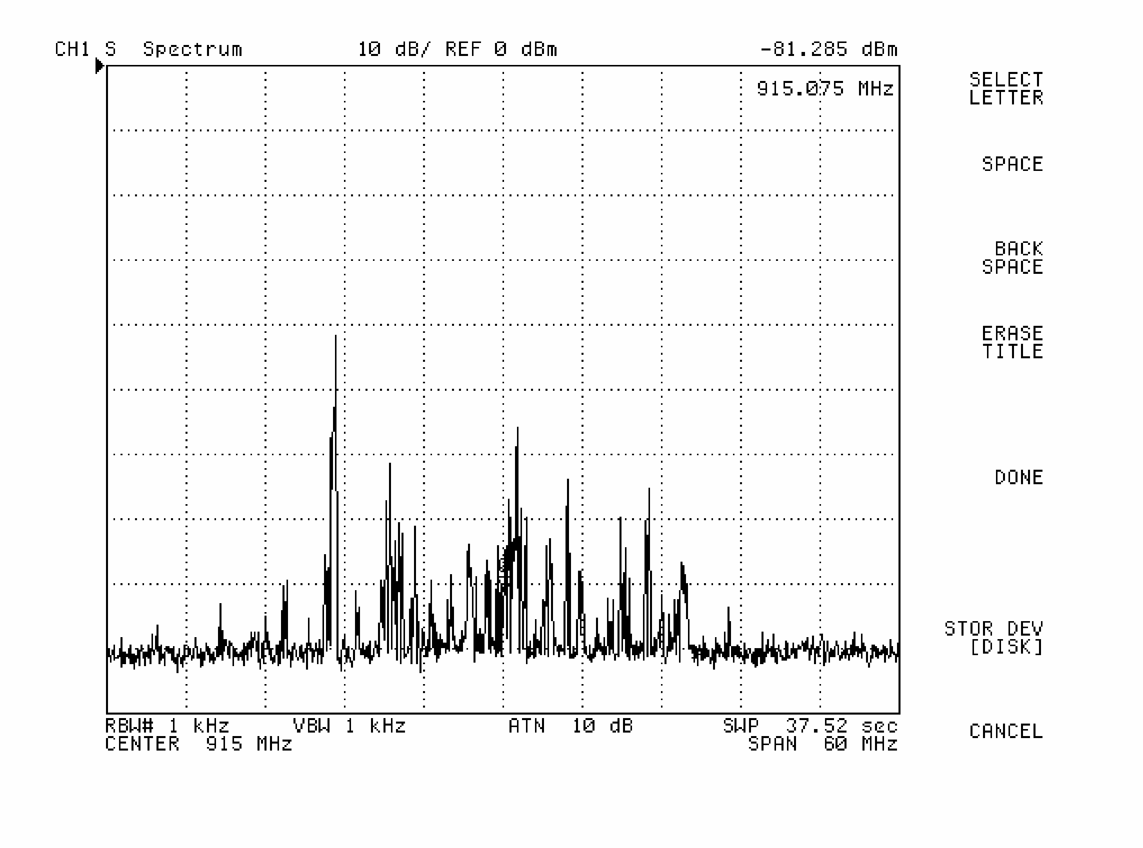


Figure 74. Astron antenna is 3 m from the transmitting antenna. The Astron antenna is in a horizontal orientation perpendicular to the face of the transmitting AWID antenna.

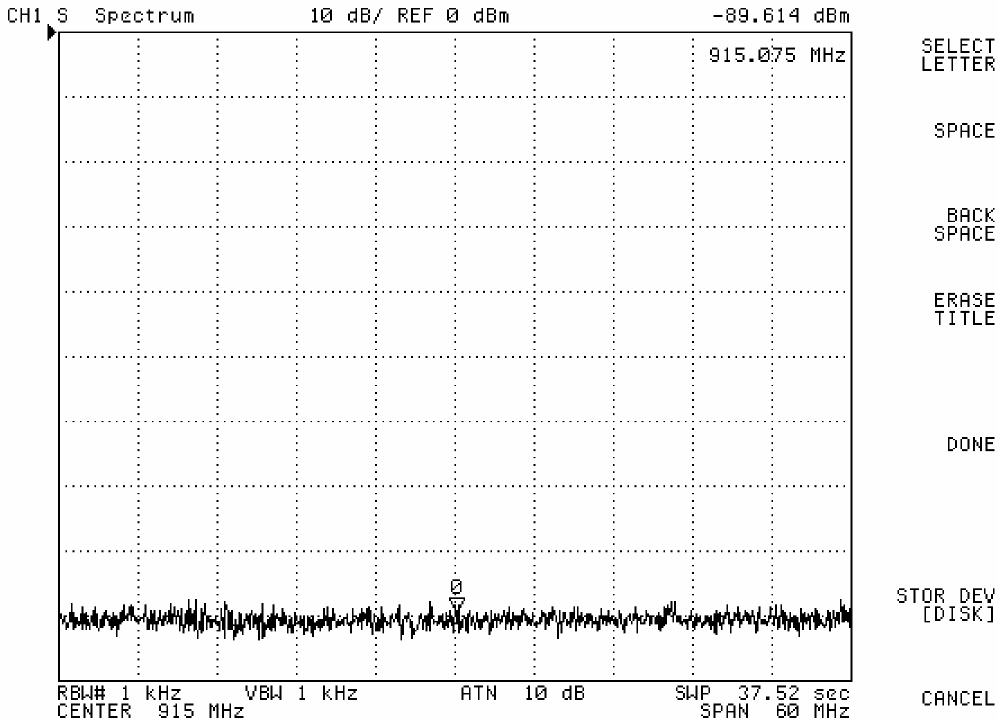


Figure 75. Repeat measurement of figures 12 and 13. Astron antenna is in the vertical orientation. UHF RFID transmitting antenna turned off.

Conclusions:

The low frequency stick antenna received the most transmitted power in the horizontal position perpendicular to the face of the transmitting antenna. The lights, air conditioner and chute hydraulics were found to have no discernible contributions to the power spectrum in the low frequency range measured.

There were spurious transmissions in the UHF band at 929 MHz and 940 MHz measured at the Beef Stocker Unit Barn. The spectrum information from the UHF antennas was inconsistent and an estimate of peak power is not achievable from the method used. It was learned after making the UHF band measurements that the transmitting electronics were using spread spectrum frequency hopping techniques.

Evaluation of KSU Beef Stocker Unit Modular Building for Electromagnetic Interferences (This is the location where transceiver read distance analyses were conducted)

EDL
Electronics
Design
Laboratory

Date: February 16, 2007

To: Dale Blasi, Professor, Department of Animal Science and Industry.

From: Russell D. Taylor, EDL

Subject: Test Results of Environment Measurements at the KSU Beef Stocker Unit Modular Building.

Spectrum analyzer measurements were taken February 15, 2007 at the Beef Stocker Unit modular building to detect the presence of RF interference. The region of interest is the spectrum immediately surrounding 134.2 KHz. Testing was completed using a TI-RFID stick antenna, part number RI-ANT-S02C, modified with a BNC connector. A Tektronix WCA280A Wireless Communications Analyzer was used to analyze the frequency spectrum in the region of interest.

With heat, lights, and vent turned off from the breaker boxes in the modular unit the spectrum was found to be free of significant RF interference. Figure 1 shows a representative screen capture for the room with all electrical components off. The two peaks at 131.9 KHz and 129.1 KHz in the figure are internal interference in the WCA280A analyzer. With the exception of these to peaks, other noise levels are below -123 dBm. Figure 2 shows the same location with heat and lighting turned on. No additive noise is detected from the lights or heating system.

Conclusion

There was no RF interference detected at the beef stocker unit modular building in the region of interest surrounding 134.2 kHz.

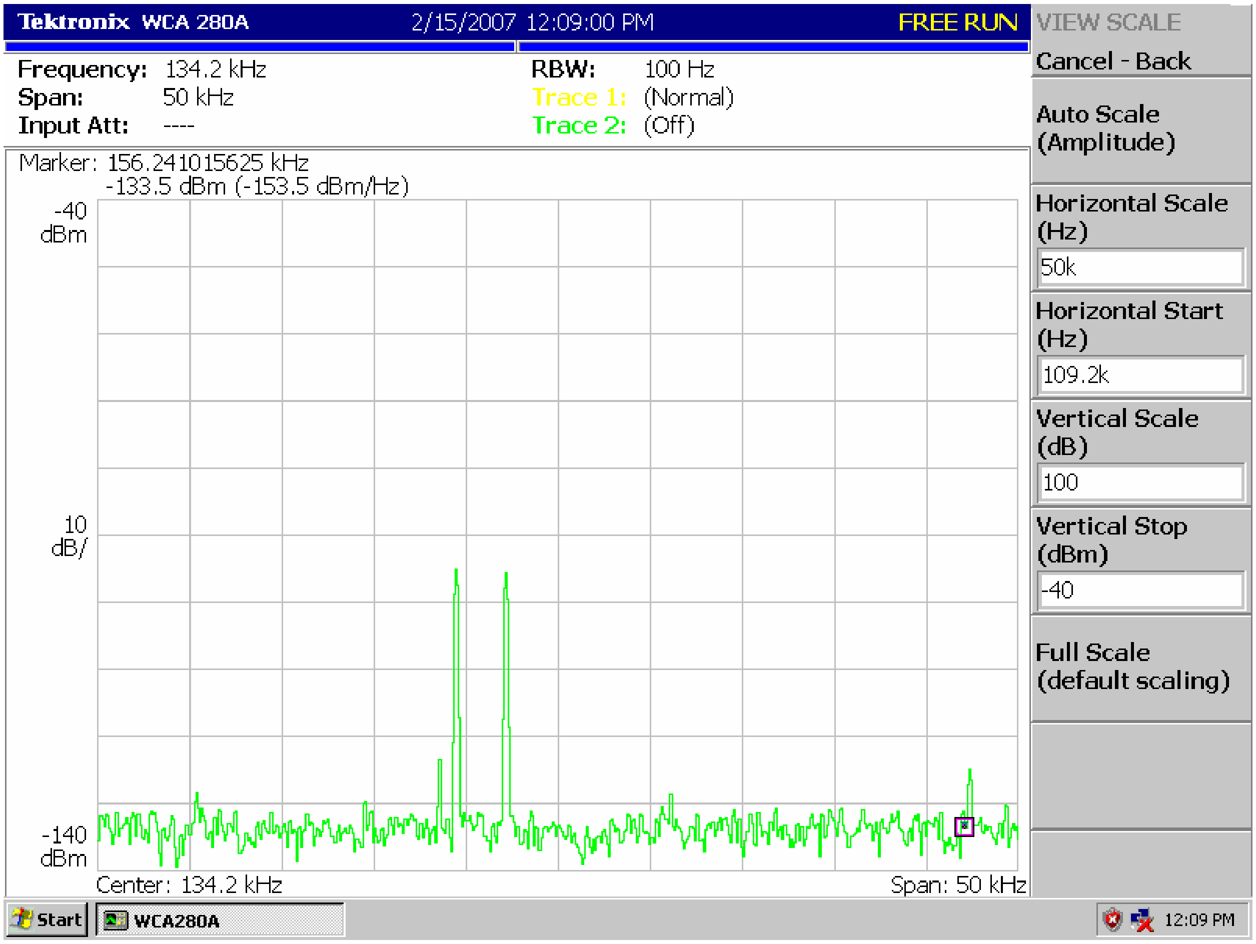


Figure 76, Measurement from the northwest quadrant of the modular unit with electrical components off.

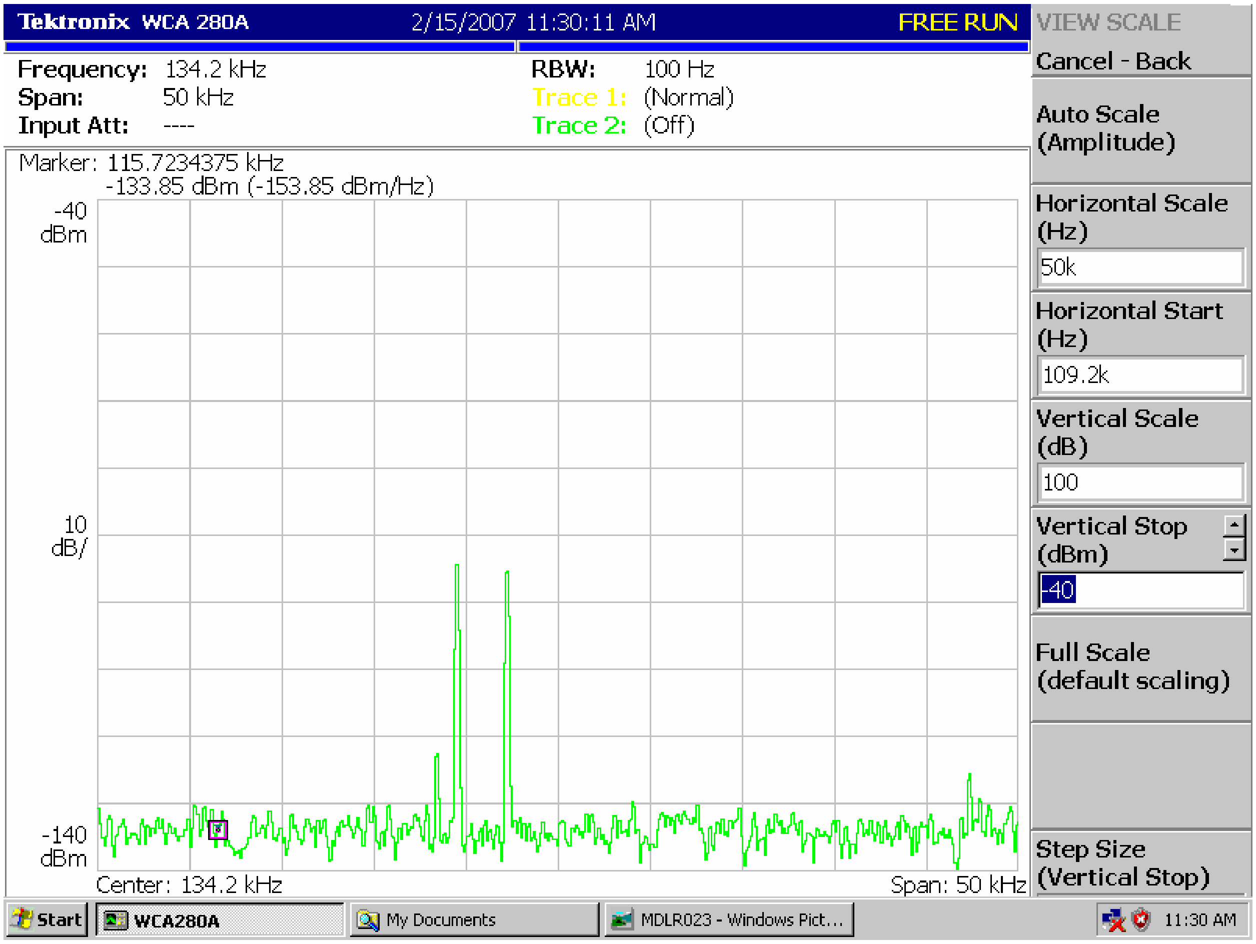


Figure 77, Measurement from the northwest quadrant from the modular unit with electrical components turned on.