

WIRELESS MODULE TRACKING SYSTEM: IMPROVEMENT AND FIELD TESTING**AJ Sjolander****J. Alex Thomasson****Ruixiu Sui****Yufeng Ge****Department of Biological and Agricultural Engineering, Texas A&M University
College Station, TX****Abstract**

Precision agriculture has enabled many producers to increase their crop outputs as well as decreasing their production costs. In the cotton industry, however, precision agriculture has not been applicable due to the process by which cotton is harvested. In recent years yield monitors have been created for cotton harvesters, to give producers a better idea about which areas of their fields are producing higher amounts of cotton. A wireless module tracking system was created by Texas A&M researchers to relate specific locations inside a field with modules of cotton. This system was extremely successful; however, it was user intensive which increased the chance of human error while operating the system. By incorporating load cells and pendulous sensors the existing system was automated, greatly reducing human interaction. Microsoft Visual Studio 2005 enabled the sensor inputs to automatically signal whether cotton was being dumped or not. This improved system was tested during the 2008 cotton harvest at the Texas A&M's Research Farm near College Station, Texas, on State Highway 50. The system worked consistently well and data were accurately stored within the system over the four day harvest period. During the harvest, two problems with the newly automated system were discovered. Wireless signals from surrounding devices were constantly detected by system's wireless transceiver; however, these signals did not adversely affect the operation of the system. Also, the harvester's basket had trouble contacting the load cells correctly due to the amount of play in the basket. Both of these problems were address and further testing in the High Plains area of Texas followed.

Introduction

With the current cotton market moving away from traditional open-end spinning to the higher-quality-producing ring spinning, the need to produce higher quality and more uniform cotton fiber is apparent. To optimize production of higher quality cotton, producers must be able to implement site-specific crop management practices (SSCMP). Including fiber-quality considerations in SSCMP has not been achievable in past years due to the process by which cotton is harvested – large field areas are harvested together with no knowledge of variations in fiber quality. The main difficulty has been tracking the field location of cotton as it is moved among the harvest and transport vehicles (harvester, boll buggy, module builder, and module truck) and finally the cotton gin. For this purpose, Ge et al. (2006) developed a wireless module tracking system (WMTS) which used GPS to assign a location (i.e., boundaries of the harvested area) within a cotton field to a specific module. When the WMTS has been used, and after a cotton module has been ginned, the fiber-quality data are accessed for the bales produced from that module. Next, fiber-quality values are averaged to get only a single value for each fiber property for each module. Using this information a module-level fiber-quality map can be produced for a given cotton field. From this map a producer can see the areas of the field that are producing higher quality cotton and those areas that are producing lower quality cotton. SSCMP can then be implemented according to this map, allowing the producer to optimize the profit they receive for their crop.

The initial testing of the WMTS was successful, and harvest information was wirelessly transmitted between the various harvesting machines. However, the system required the operator to press a series of buttons during each cotton transfer. If the operator forgot to press this series of buttons, the system would continue operation based on the previous basket number and thus assign GPS coordinates for one basket to the following basket. To reduce the likelihood of this error, as well as to reduce the operator's responsibility for the system, the system needs to be automated.

Therefore, the objectives of this work were (1) to develop a system that would automatically initiate wireless transfer of data among field machines based on their dumping action, which is a normal occurrence during harvest; and (2) to field test the system for applicability in a real-world harvesting operation.

Materials and Methods

System components

Multiple sensors were utilized to automate the wireless module tracking system. An inclinometer (H4A1-70, Rieker Inc., Aston, PA), which measures tilt angle, is the primary device. By mounting the inclinometer on the cotton harvester basket, the system can know when the basket is raised and in the dump position. Sometimes, however, the basket can be raised while no transfer of cotton takes place or only a partial load is transferred. To account for these false or partial dumps, two load cells (LC307-5K, Omega Engineering Inc., Sunbury, OH) are installed on the main basket support beam. The load cells are used to determine whether there is a difference in the weight of the basket between prior to being raised and after being lowered. If there is no difference, then the system knows that no transfer of cotton has taken place and therefore it is not to initiate wireless transfer of basket information to the boll buggy or module builder. In the event that a significant partial dump (as determined by a significant change in basket weight) has occurred, the load cells will initiate wireless transfer for the current dump, and current basket ID information will be maintained for the subsequent dump when the remainder of cotton is released. The final piece of equipment required by the wireless module tracking system was a GPS receiver (MR-350, Global Sat, City of Industry, CA), which enables relating specific areas of the field to specific modules so that module maps and fiber-quality maps can be created.

A yield monitor (Mississippi Cotton Yield Monitor, Mississippi State University, Mississippi State, MS), was also installed on the cotton picker used to test the automated WMTS. The yield monitor was used (1) to determine whether any relationship existed between certain fiber-quality properties and the yield from that specific area of the field, and (2) to enable profit mapping of the field by considering yield and fiber quality together to determine revenue at each field location.

All of the above sensors were integrated with a single data-acquisition system. The data-acquisition system stores all of the data from the sensors in a single data file. For ease of processing, each basket of cotton harvested has its own file, and all of the files from a given day are stored in a common folder. A post-processing step is required upon completion of a single day's harvest; this step allows for all the individual basket information to be combined into a single file.

The data-acquisition system is based on a single-board computer (SBC) (MicroPod, RLC Enterprises Inc., Paso Robles, CA) that uses the Windows CE operating system. The data-acquisition system has the capability of handling many tasks at the same time without slowing down the processing speed of the system. Microsoft Visual Studio 2005 was used to write all of the program code in Visual Basic. Figure 1 below shows the screen that an operator sees while harvesting. The values for the sensors are voltages, but in later versions these values will be converted into more relevant numbers like pounds so that the operator has a better idea of what is taking place.

The 'Harvesting' screen displays the following data and controls:

Longitude	-9625.905	Wireless Message MTOH,01001,37777 MTOH,01002,37777 MTOH,01003,37777
Latitude	3031.746	
Yield 1	0.159	
Yield 2	0.552	
Inclinometer	2.46	
LoadCell 1	0.545	
LoadCell 2	0.552	
Basket #	004	

Controls: Dump, Start, Pause

Figure 1. Harvesting operating screen.

Available within the program are options allowing the producer to group harvesting information for specific fields. Figure 2 is the main screen seen by the operator when the program is initiated.

The 'MainForm' screen displays the following options and information:

Cotton Harvest Information System

New Harvest	Return Harvest
Post Process	Component Test
Exit	About

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Figure 2. Startup screen for program.

Lab testing

Testing within the lab was completed by simulating cotton transfers between equipment. With voltage regulators (6234A, Hewlett Packard Company, Houston, TX), the weight and angle of the cotton harvester's basket were varied to simulate cotton being added to the basket and then the basket being dumped. Once the program's functionality was verified, the load cells and inclinometer were connected to the data-acquisition system and tests were repeated. To simulate cotton entering the basket, the load cells were placed in a 5 ton hydraulic press (4350.L, Carver Inc., Wabash, IN), and the pressure exerted on the load cells was varied over time. Cotton leaving the basket was simulated by simply holding the inclinometer in a vertical position and rotating it in the air. Next, the module builder subsystem was set up approximately 20 feet from the harvester subsystem and the wireless transmission was tested. Cotton entering and leaving the basket was simulated with the hydraulic press and by rotating the inclinometer in the air again.

Field tests

After confirming that the system was working properly, all of the sensors were mounted onto the cotton harvester being used. Figure 3 shows the sensor mounting locations on a cotton picker. Installation of the load cells was tedious, and therefore their installation should generally be considered permanent, while the data-acquisition system (as well as the inclinometer) was easily installed and can be removed from the harvester with the sensors being kept in place but unplugged from the data-acquisition system.

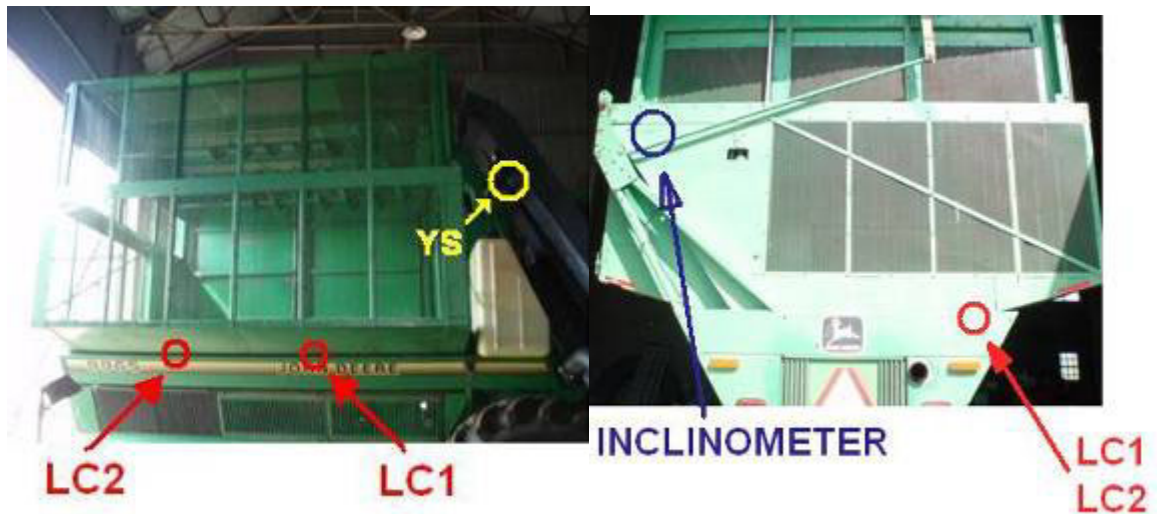


Figure 3. Sensor mounting locations. LC1 and LC2 refer to load cells 1 and 2, while YS refers to a yield sensor.

After mounting, the system was tested again. Only the unloading of cotton was simulated since it was difficult to vary the weight and simulate cotton entering the basket. The cotton harvester's basket was raised and lowered to simulate the unloading of cotton, and the successful transmission of the wireless message was confirmed. Also, to ensure that the load cells were working properly, the change in voltage between the basket's down and up positions was observed. The change in voltages from the inclinometer and load cell sensors can be seen in figure 4.

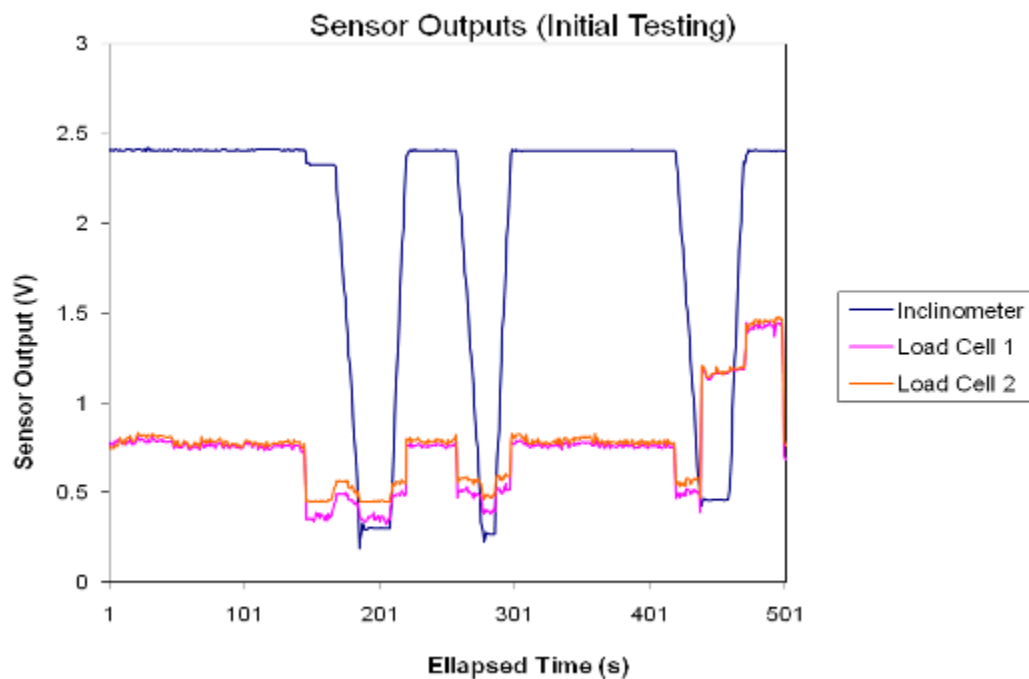


Figure 4. Load cell and inclinometer output data (initial testing).

When the inclinometer's voltage falls below 1.2 Volts, approximately 45 degrees above horizontal, the basket is considered as being raised to the dump position. As the inclinometer's output drops, the values for the load cells are decreasing since they are no longer supporting the weight of the basket.

The automated WMTS was installed and tested first on a cotton picker (9965, John Deere, Moline, IL) used for the harvest at Texas A&M's IMPACT Center research farm near College Station, TX, and later on a cotton stripper (7450, John Deere, Moline, IL) at a farm near Lubbock, TX. The harvest near College Station took place from September 22-25, 2008, and approximately 32 ha (80 ac) of cotton was harvested over the four days. For the entire testing period a boll buggy was not used, only the cotton picker and a single module builder (CBSK Module Builder, Crustbuster Speed King, Dodge City, KS). Each day prior to the start of the harvest the system was initialized and data collection began. Each day during the filling of the first basket of cotton an additional rider sat in the cab of the cotton picker to ensure the system was working correctly. After the first basket was collected the harvester operator was asked about the condition of the system during each subsequent unloading of cotton. Once the harvesting was completed each day, the data were downloaded from the data-acquisition system and analyzed. The harvest near Lubbock took place from November 21 thru December 7, 2008, and approximately 81 ha (200 ac) of cotton was harvested on ten days during that period. For the entire testing period the cotton stripper dumped solely into a boll buggy (CBSK Boll Buggy, Crustbuster Speed King, Dodge City, KS) which dumped solely into a single module builder (Cmb 6932, Bush Hog, Selma, AL). Each day prior to the start of the harvest the system was initialized and data collection began. As at the IMPACT Center, each day during the filling of the first basket of cotton an additional rider sat in the cab of the cotton stripper to ensure the system was working correctly. After the first basket was collected the harvester operator was asked about the condition of the system during each subsequent unloading of cotton. Once the harvesting was completed each day, the data were downloaded from the data-acquisition system and analyzed.

The downloaded information was used to create yield, module boundary, and fiber-quality maps. All of the data gathered during the harvest was imported into ArcGIS 9.2 and maps were subsequently produced. Yield sensor data had to be converted from voltages to mass flow rate values to create a yield map. Equation 1 was used to determine a yield coefficient.

$$Y = \frac{M}{V} \quad (1)$$

Where:

Y = Yield coefficient (lb/V)

M = Module Weight (lb)

V = Sum of all voltage values per module (V)

Next, the original voltage value was multiplied by the yield coefficient as shown by equation 2.

$$Q = v \cdot Y \quad (2)$$

Where:

Q = Cotton Flow rate (lb/s)

v = Voltage per second (V/s)

Y = Yield coefficient (lb/V)

Fiber-quality information was obtained from Scarmardo Gin in Caldwell, TX, where the cotton was ginned. Bales from a single module had their fiber-quality characteristics averaged together so that only a single value per module was used to map each characteristic. This information was then related to the harvest information (position and yield) for each corresponding module.

Results and Discussion

The field testing of the automated WMTS during the 2008 cotton harvest season at Texas A&M's IMPACT Center was partially successful. Data gathered throughout the harvest were stored on the data-acquisition system's memory in files that corresponded to individual baskets of cotton produced by the harvester. Each of these text files was

stored in a single folder that specified on what day the harvest took place. Upon the completion of each day's harvesting, the data were post-processed for analysis in the lab, affording a chance to observe whether the sensor data had been correctly stored in the data-acquisition system in the field. The post-processing step worked as designed, combining all of the day's basket information into a single file. A header was inserted into the file to help the user understand the file's sensor information.

With the data recorded during the harvest as well as the information from the classing office following ginning, yield and fiber-quality maps were produced. Ultimately, these maps could inform a producer which areas within a field need more attention to increase the quality of or profit from the crop. Figure 5 includes a yield map (some data missing) produced from the IMPACT Center harvest data and a module boundary map. Only part of the field was irrigated, and it is visible from the yield map which area was covered by the center pivot.

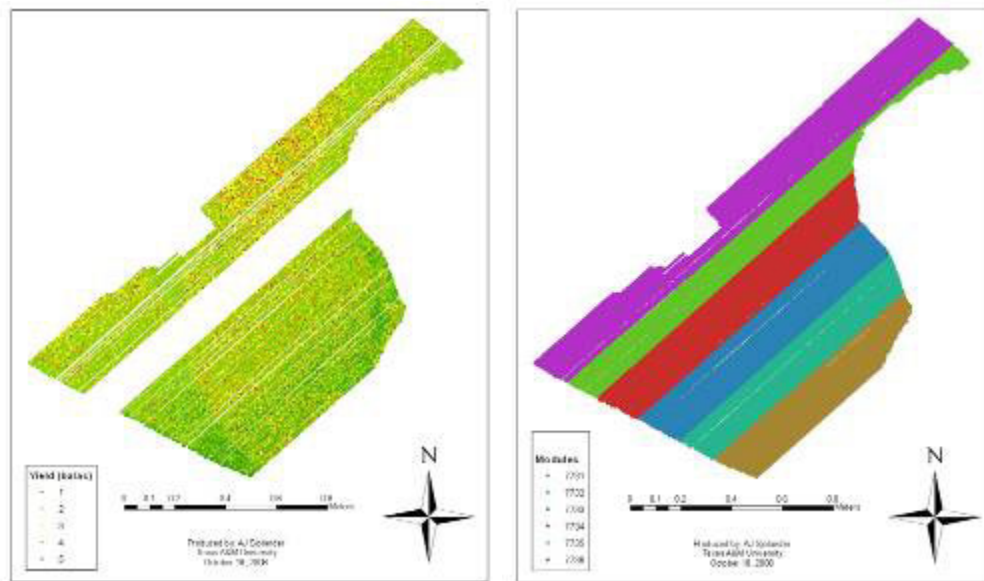


Figure 5. Yield and module boundary map of IMPACT Center.

Module-level fiber-quality maps were also produced (figure 6) after module averages of several fiber-quality parameters were applied back to the module-boundary map. These fiber-quality maps show how the different cotton properties change as one moves throughout the field. For instance, it is clear that the strength in the middle of the field is higher than the strength on either edge of the field.

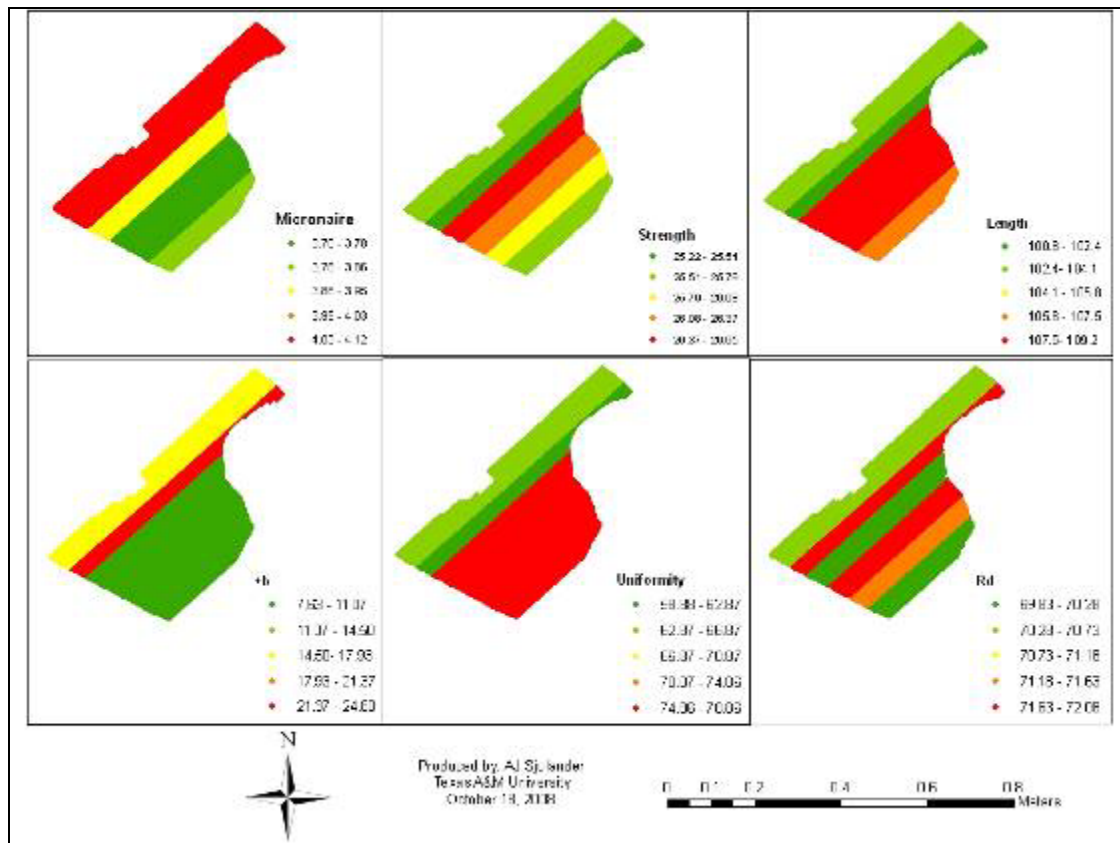


Figure 6. Module fiber-quality maps at the IMPACT Center.

A couple of flaws were noticed during field testing of the automated WMTS near College Station. The first was interference from other wireless devices. During field testing, a fellow researcher was testing an automated module builder system which transmitted information from a computer through a separate wireless transceiver to controls within the module builder cab. These signals were picked up by the WMTS's wireless transceiver. Figure 7 below shows wireless signals received by the transceiver as well as how the signals should have appeared.

Received Message	Expected Message
<p>Wireless Message Received from Module Builder:</p> <pre> ? A E?Z?F???B??z D??_E??0? ?N3142J < @ ? *3142J < *MTOH,01001,07732 A A R+10721. F+12027. V3 E00 99 M96 A1 L+10721. C2410 *3142J @ ? </pre>	<p>Wireless Message Received from Module Builder:</p> <pre> MTOH,01002,07732 MTOH,01003,07732 MTOH,01004,07732 MTOH,01005,07733 MTOH,01006,07733 MTOH,01007,07733 MTOH,01008,07733 MTOH,01009,07733 MTOH,01010,07734 MTOH,01011,07734 </pre>

Figure 7. Received and expected wireless messages.

This flaw was not a major problem since the wireless signals sent by the WMTS's module builder subsystem were recognizable among the extraneous signals (highlighted in within received message in figure 7). After some post processing of the data the unimportant wireless signals were removed, leaving only the signals from the WMTS.

The larger problem was that, while the inclinometer functioned as designed and triggered wireless message, the load cells did not work properly. Because of play in the basket relative to the rest of the cotton picker, the contact points attached to the bottom of the cotton picker basket regularly slid off of the load cells as the harvester moved throughout the field. This resulted in the load cells not producing any output values as well as putting high amounts of stress on the load cell mounting hardware. In figure 8 it can be seen that when the inclinometer voltage varied strongly in association with a basket dump, the load cell voltage did not experience a change as it should have (recall figure 4, produced from initial tests).

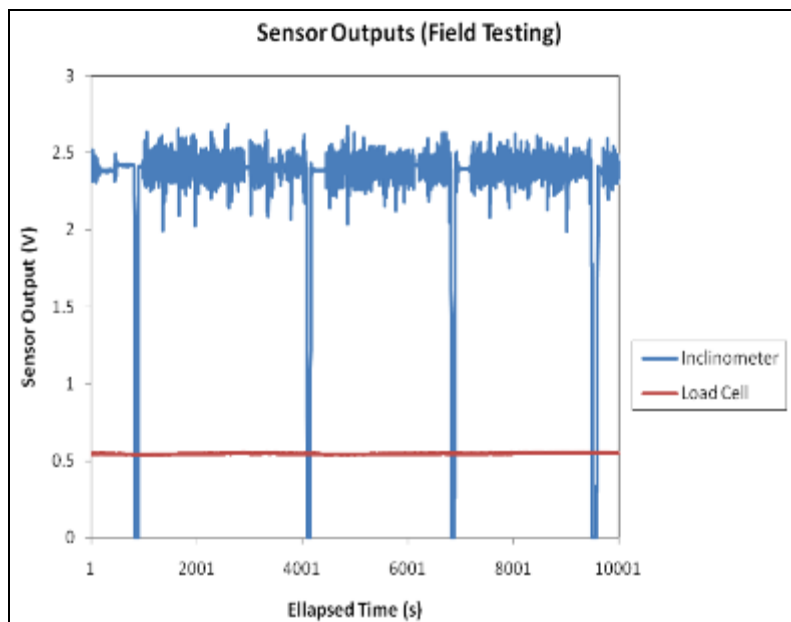


Figure 8. Field testing (IMPACT Center) inclinometer and load cell output data.

Prior to the field test at Lubbock, a software filter was designed so that the WMTS would recognize only those signals sent from its subsystems. Also, a new load-cell-to-basket contact point concept was developed which relocated the contact points from the bottom of the basket to the top of the load cell. When the contact points were on the basket, the basket had to be lowered into a precise position and could not move more than 6.35 mm (0.25 in) from that location without sliding off the load cells. It became apparent that the basket flexes and moves more than this while the harvester traverses a field. Having the contact point on the load cell will allow for the basket to move significantly while staying in contact with the load cell. In the Lubbock field test, the system worked as desired with no interference from surrounding wireless devices, and the load cells correctly output data. Figure 9 displays the sensor outputs from one of the testing days in Lubbock.

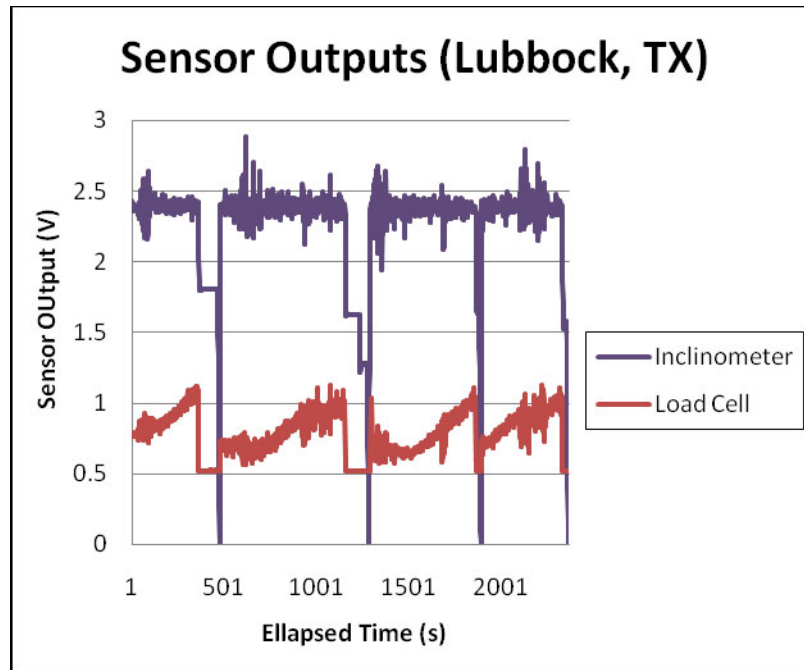


Figure 9. Field Testing (Lubbock) inclinometer and load cell output data.

The large dips in the inclinometer line in figures 4 and 8 represent the basket being raised. The load cell line in figure 8 gradually increases, meaning that cotton is entering the basket, and then decreases sharply at the same point the inclinometer does. This decrease in the load cell line occurred because the load cells were no longer supporting the basket when it was raised.

Discussion

The fundamental aspects of automating the WMTS have been completed, so now the data required for mapping fiber quality can be generated automatically. It should be noted that producing fiber-quality maps on a module basis gives producers an idea about only fairly large areas of their fields. Ideally, producers would be able to create fiber-quality maps on a finer scale. For this to be possible an in-situ fiber-quality sensor would need to be present on the harvester to measure fiber quality in real time throughout the field. Such a technology does not currently exist. However, even if such a sensor became available, the WMTS would still be a very useful asset to cotton producers. Since an onboard fiber-quality sensor would measure the cotton's quality prior to ginning, if the WMTS were also used the post-ginning fiber-quality information could be used to calibrate field data on a module basis, quite a high-level calibration.

Conclusion

Hardware and software modifications to the wireless module tracking system enabled it to be automated and therefore eliminated the need for user interaction. Initial testing of the enhanced system was successful, with information being sent automatically to and from the different harvesting machines. Problems with the load cell mounting equipment and the interception of wireless signals from surrounding devices were realized during the system's initial testing near College Station, TX, but these problems were addressed prior to further testing of the system in Lubbock, TX. None of the problems experienced during the first field test were present during follow up testing, and the automated WMTS worked as designed, automatically recording harvester-basket position data and transmitting basket ID information with each dump.

Acknowledgements

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References

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