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Work in Progress: RFID Sports Timing System

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Abstract— **Timing plays a critical role in most sporting events. RFID-based timing solutions offer a high level of automation. Current timing solutions are high in cost and frequently do not offer live results to spectators. Existing RFID hardware is evaluated for suitability in a new timing solution. An architecture for an open source timing solution is then evaluated. The new solution offers a novel combination of features making ownership feasible for smaller sporting events.**

I. Introduction

Modern sporting events require accurate, sub-second race timing. Events with hundreds of participants generally accomplish this by tracking Radio Frequency Identification (RFID) transponders attached to the athletes. Cost typically prevents small-scale sporting events from owning this equipment. Therefore, they must outsource it to a company specializing in timing. Unfortunately, no features beyond authoritative results are typically delivered by such companies at affordable prices. For example, two companies used by one small sporting event lacks both the equipment and experience to provide live real-time results to spectators [1], [2]. Even the accuracy of the authoritative results has been questionable at times.

The ideal solution for many of these small sporting events is to own timing equipment for maximum flexibility. Such equipment must accurately track athletes using RFID to provide accurate, authoritative results under race conditions. Ethernet connectivity must be provided so that real-time results can be tracked over a standard network. Additionally, timing equipment must be relatively easy to configure and use, available at low cost, and created with an open-source mindset to allow for new and innovative additions to the system by others. Equipment must be small, portable, and waterproof. Because no system with these features exists, the goal of this project is to develop a system so that even small-scale events can have access to feature sets typically seen only at large events. This paper will focus primarily on the RFID aspects of this system.

II. Background

A range of products and services exist that can be used to serve the needs of sporting events that require timing. Technologically, the simplest method is to manually enter racer bib numbers into timing software as racers cross a checkpoint, as no special hardware is needed and a simple database can be created to track and store the timing information. However, this method requires alert individuals to watch the race and is imprecise. Therefore, hardware is used to greatly increase precision and reliability. Systems designed for more than a handful of participants generally use some form of RFID. When RFID transponders are worn by athletes, a completely automated timing system may be developed.

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An additional timing mechanism used by some events is photo finish. This method relies on a high-speed line-scan camera, such as EtherLynx, to take a continuous photograph of participants crossing a checkpoint [3]. It is useful for determining the true winner when there appears to be a tie. An event can choose to use a photo-based system instead of an RFID-based system, but this would require a large amount of manual labor interpreting and verifying the photographs. Therefore, most large events with hundreds of participants choose to use RFID.

Many event organizers lack the experience and the equipment to run their own timing system, so they contract with companies to serve the event. These companies use RFID-based timing systems. Serving a small sporting event in the south Florida area can cost from $1000 to $2000 [4]. This has been the experience of the Sunbelt / Cohutta Springs Triathlon as well [1], [2]. Services provided are generally minimal and do not include live results provided on televisions, intermediate results generated by RFID readers in the middle of a split, or live web results. They sometimes are forced to work with timing data by hand, potentially introducing human error, to generate reports in order to handle the unique timing structure of a race. The RFID readers generally used are poorly interconnected, a requirement of any system delivering live results to spectators.

These contractors and major event planners purchase end-to-end timing systems from companies specializing in sports timing. Major companies include ChampionChip [5], IPICO Sports [6], RFID Race Timing Systems [7], and AMB Identification and Timing [8]. They each implement their own proprietary system and generally are not guaranteed to interoperate. In addition, they are prohibitively expensive for many small events, starting at $55,000 for a basic system with 4 readers, 16 antennas, and 1,000 tags. This cost is too high for the budgets of many small events and completely rules out the possibility of having numerous readers throughout the course to track progress. For some systems, further costs would be involved in purchasing or developing appropriate software to manage and deliver live results via various mediums.

Work has been started on an open source hardware and software design to address these issues. An initial hardware and software design for an Ethernet-connected timing station was created. Two RFID readers were studied for use in this station. A low-cost RFID reader was evaluated. However, the read range of this reader was found to be inadequate for the application. Therefore, further evaluation of other RFID readers is needed.

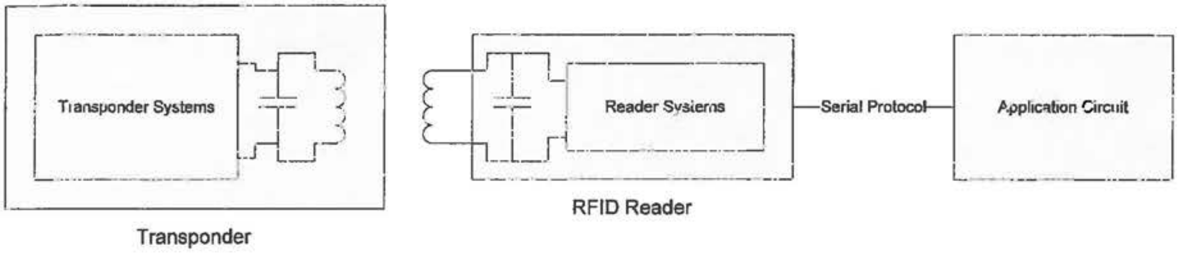

Fig. 1. The basic structure of an RFID deployment using off-the-shelf RFID hardware consists of transponders, readers, and an application circuit that utilizes the RFID hardware. In this diagram, the passive transponder is charged by the reader using inductive coupling. It transmits a unique identifier back to the reader, which is then utilized by the application.

TABLE I
COMPARISON OF TRANSPONDER TYPES

Feature	Passive	Active
Self-powered	No	Yes
Cost	Low	High
Read Range	Low	High
Reader Antenna	Small	Large
Sensors	No	Yes

III. RFID OVERVIEW

Most small events choose to go with a solution based only on RFID to avoid the complexities and work involved with a photo-based solution or the lack of precision and possibility of error with a manual timing solution. The system described by this paper also uses a proven RFID-based solution. Therefore, an understanding of RFID technology is critical.

No matter what RFID vendor is chosen, a basic RFID setup in any application consists of transponders, antennas, and RFID readers (Fig 1). Transponders and readers are typically purchased off-the-shelf from a vendor, while antennas are often customized for the application.

A. Transponders

Active and passive transponders are generally used (Table I). Active transponders contain a long-lasting battery and are therefore more reliable and have a greater read range. They may also be equipped with data-logging sensors for specific applications [9]. Antenna design and deployment for active transponders is much simpler than antenna design for passive transponders. Due to the high cost of active transponders, they will not be considered further in this paper.

A typical passive transponder consists of an antenna, a capacitor, and a chip (Fig 1). The antenna and capacitor are tuned at the factory to resonate at a specific frequency. The reader powers the transponder by energizing the reader antenna, which in turn powers the transponder through inductive coupling. The chip inside the transponder, now fully powered, is free to transmit a unique identification code back to the reader [10], [11]. This transmission should only commence when the voltage on the capacitor has reached a sufficient level to adequately power the components of the transponder [12]. The transponder's processor must also require a small amount of power, as high instantaneous power demands reduce read range [13]. Note that the position of the antenna in relation to the readers antenna is critical in order to maximize read range [14]. All loops in the two antennas must be in parallel planes. Antenna position may dictate which off-the-shelf transponder can be used.

B. Antennas

The antenna connected to the RFID reader is typically customized for the application. The inductance of the antenna must match the required inductance of the reader so that the system resonates at the proper frequency for the transponder. Because this requirement can vary widely, the choice of reader has a significant effect on the design and cost of the antenna. The dimensions of an antenna should be sized approximately to scale with the size of the transponders antenna. If the reader antenna is too small, the field strength around the antenna will not be large and read range will be limited. If the reader antenna is too large, among other negative effects, the reader will not have enough power to maintain the field strength, and field strength will again be limited. Determining the proper reader antenna size for an application appears to be best left to experimentation and others' past experience with similar application setups.

A single reader antenna is normally connected to a single RFID reader module. A single antenna often cannot be constructed large enough or in the appropriate shape for an application while maintaining the desired read range, so antenna multiplexers can be used to connect multiple smaller antennas to a single reader. Multiplexers, which are cheaper than readers, are used to reduce the number of readers required in an application, thus saving cost and power. Additionally, if the antennas are close together, as they are in this application, only one antenna may be energized at a time to avoid interference. A multiplexer is the obvious cost-effective solution to this problem. Because antennas are energized less frequently in a multiplexing setup, transponders passing over the antennas must move slower in order to be detected. Due to the effect of multiplexing on the Q factor, a measure of antenna efficiency, excessive multiplexing also has the possibility of reducing read range [15], [16].

A major choice when choosing RFID hardware is the desired operating frequency of the system. Higher frequencies do not penetrate conductive materials and liquids as well as lower frequencies [17]. However, higher frequencies also offer smaller, cheaper transponders and faster identification. In practice, high frequency readers and transponders, as implemented by the vendors, tend to do a better job of handling multiple transponders in the field at once.

Although low frequency transponders cost more than high frequency transponders, off-the-shelf high frequency readers tend to cost significantly more. For example, a complete TI Series 2000 low-frequency reader module costs $529 and a basic TI Series 6500 high-frequency long-range reader costs $1,548 [18]. By asking racers to buy and keep the transponders, it is also feasible to pass off the slightly higher costs of low-frequency transponders as part of a racer registration fee. Low-frequency transponders have been proven to work in this application by ChampionChip, a significant member of the sports timing market. Therefore, two low frequency readers were investigated for this paper for potential use in a sports timing application.

ChampionChip and RFID Race Timing Systems both use passive 134 kHz RFID systems from Texas Instruments. This reduces performance but ensures that the transponders work in harsh environments. IPICO Sports uses a dual frequency system of 125 kHz and 6.8 MHz. This results in excellent performance that still works in harsh environments, but it increases system complexity since it must cope with different frequencies. Unlike the other systems, AMB-IT transponders contain a battery, which greatly increases transponder costs.

IV. Low Frequency RFID Readers

A low frequency Texas Instruments transponder operating at 134.2 kHz was chosen for this application [19]. The transponder is contained in a hermetically sealed glass tube measuring 3.85 x 31.2 mm. It contains a unique 64-bit read-only memory programmed at the factory. As indicated in the reference guide, the optimal read position for this transponder is perpendicular to the plane of the RFID readers loop antenna [20]. Therefore, it is ideal for vertically-mounted use in an ankle band in a triathlon scenario. Alternative Texas Instruments low frequency transponders could be used for other types of athletic events when ankle bands are not appropriate.

Two RFID readers were investigated for use in reading these transponders from Texas Instruments. An inexpensive Intersoft Corp. reader capable of reading Texas Instruments transponders was tested. During testing, it became clear that it would not meet the requirements of this application primarily because the reader exhibited a poor read range. The Series 2000 reader components from Texas Instruments were also investigated for use in this application and will be tested when parts become available.

A. Intersoft

The TRRO1OEM-HDX [21] is a small (60 x 50 x 5 mm) RFID reader module capable of reading Texas Instruments low frequency transponders. Before the TRRO1OEM-HDX became available, a TRRO1OEM [22] module was also initially tested, which reads 125 kHz transponders from Intersoft. Several of these 125 kHz transponders of various sizes were tested in addition to the Texas Instruments glass transponder previously described. An RS232 interface for host communication and all radio front-end hardware is onboard an Intersoft RFID module. A basic Intersoft reader setup consists of the RFID reader board itself and a simple loop antenna. A 6V - 16V DC power supply is also needed, which is then linearly regulated by the reader. To aid testing, an LED on the board is illuminated when a transponder is detected by the reader.

Both Intersoft readers require a relatively high inductance for the antenna. For example, the TRRO1OEM-HDX module requires a $0.43mH$ coil. This requires many turns of magnet wire to construct an antenna of approximately 12 inch diameter. Several antennas of varying sizes were purchased from Intersoft for use with the TRRO1OEM reader. In addition, a custom rectangular antenna specific to the size required for the desired application was also constructed for the TRRO1OEM-HDX reader. No tuning functionality is provided by Intersoft to achieve the exact resonance frequency. One is forced to adjust the antenna until resonance is achieved or purchase an antenna from Intersoft that has been constructed to match the specifications of the reader. A potentiometer is included onboard to adjust the impedance of the antenna. Intersoft does not provide any antenna multiplexing hardware, so a custom multiplexer board was designed and built utilizing solid state relays.

No antenna/transponder combination was able to achieve a read range beyond 12 inches, at best. No increase in read range was noted in switching from a 12 inch diameter antenna to a 14 inch diameter antenna, so antenna size was not a limiting factor. Multiplexing antennas worked flawlessly and did not further reduce read range. Intersoft readers do not appear to support multiple transponders in the antennas field at all. No transponder is read if more than one is present. A linear regulator is present on the reader, so increasing the supply voltage to the reader had no effect on read range. The reader is simply underpowered for a sports timing application, as the read ranges achieved were woefully inadequate. The failure to support multiple transponders is also a drawback, although the limited antenna sizes would likely mitigate this, as numerous antennas would be used in a real antenna mat if read ranges were otherwise acceptable.

B. Texas Instruments

Texas Instruments sells a number of low-frequency RFID components under the name of Texas Instruments Registration and Identification System (TIRIS). Most reader components are sold under the name Series 2000. These components vary widely in cost, functionality, and read range. The Series 2000 Micro Reader is a small, inexpensive, self-contained module containing everything needed for adding an RFID reader to an application [24]. Unfortunately, it only offers a read range of up to 4.5 inches with the chosen 32 mm transponder [25], [26] and requires a very specific antenna inductance, so it has not been chosen for evaluation. Building a Series 2000 reader appears to be the right path to take, as read ranges

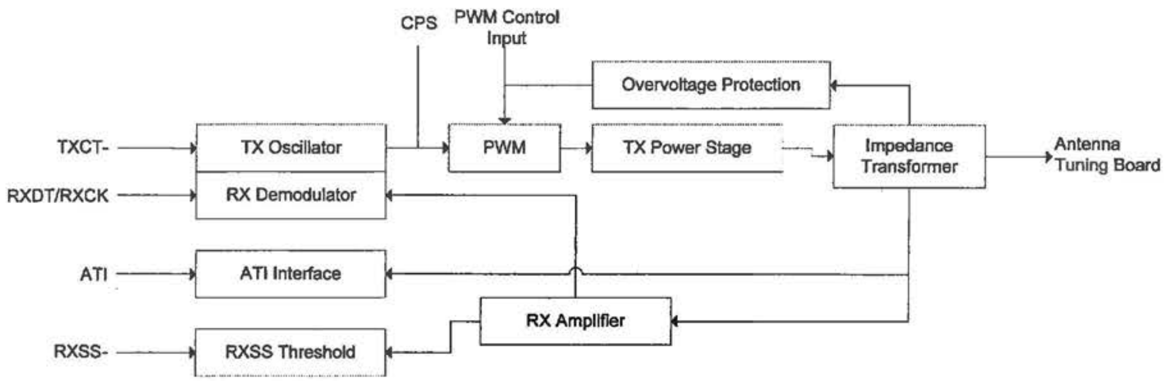

Fig. 2. A Texas Instruments Radio Frequency Module (RFM) interfaces between the reader's loop antenna and a digital control module. It energizes the field when necessary at the power levels specified by the Pulse Width Modulation (PWM) signal. It also demodulates the transmission from the transponder [23].

of 21 inches are achievable with the chosen transponder and antenna configuration [27]. Although Texas Instruments offers prebuilt ready-to-use Series 2000 readers [28], they are only recommended for use with official Texas Instruments antennas due to the narrow tolerances for inductance on the antennas and limited tuning capabilities. Therefore, a custom Series 2000 configuration is proposed. Evaluation and testing of Series 2000 RFID components for a sports timing application will commence as they become available. Product availability is currently limited due to new European environmental regulations taking effect.

A basic Series 2000 reader configuration consists of a control module, a radio frequency module (RFM), and an antenna. A control module and RFM are stacked to form a complete reader. The control module provides a serial interface and runs the logic necessary to communicate with the transponder. The basic control module supports an RS232 serial interface. A control module supporting RS422/485 is also available [29]. Both control modules can interface with any RFM. Unlike the Intersoft module, a Texas Instruments reader can more gracefully handle multiple transponders in the field. The transponder with the strongest signal will be read. This reduces the chance of a miss.

The RFM contains the analog components necessary to interface between the logic of the control module and the antenna (Fig 2). One of the ways read range is directly affected is by modifying the supply voltage to the RFM. Three RFMs are available. A small, low power RFM, known as the Mini RFM is targeted for small hand-held units [30]. It can only handle a low supply voltage, so read range would be limited. The Standard RFM offers significantly higher power output, but includes a limited number of tuning components onboard that restricts antenna inductance to $27\mu H$. A wider range of antenna inductances are possible with the Remote Antenna RFM. The Remote Antenna RFM does not contain any tuning capacitors and therefore relies on a separate antenna tuning board that can handle antennas with inductances from 8 to $80\mu H$. This tuning board contains a large number of capacitors and a variable inductor to tune any antenna to resonance [31]. A multiplexer, discontinued by Texas Instruments and now sold by Oregon RFID, allows the use of up to four antennas and four tuning boards with a single Remote Antenna RFM [32].

Antenna design for high-powered Texas Instruments RFMs is different from the design of an antenna for use with an Intersoft reader. A typical inductance of $27\mu H$ is targeted. This contrasts with the $430\mu H$ required by the Intersoft reader. Therefore, fewer turns of wire are required. Due to the high currents, thicker gauge wire is needed. Texas Instruments recommends the use of Litz wire, which consists of many individually insulated thin wires twisted together, to increase antenna efficiency.

RFMs do not further regulate the supply voltage, so the supply voltage used has a direct impact on read range. Supply voltages up to 24 VDC are possible. Because the supply is used directly, it is particularly sensitive to noise. Texas Instruments recommends the use of a linear power supply due to the ripple in a switched power supply. If a switched power supply must be used, the frequency must be > 200 kHz.

V. High-level Overview of System

A sports timing system delivering live results to spectators both at the event and over the Internet requires a large number of components and interconnections. To simplify this design, TCP/IP over Ethernet is used so that as much off-the-shelf hardware can be used as possible in the creation of a network topology. A server placed on a switched local area network (LAN) plays a central role. It runs a database server used for storing live timing results. A web server provides reporting and registration capabilities. A custom service allows for communication with RFID stations. Finally, it runs a standard network time protocol (NTP) server so that all remote nodes on the network may run on the same clock. Registration PCs running a standard web browser can be used by volunteers to associate RFID transponders with racer names and bib numbers on race day, among other registration tasks. Results terminals running a full-screen web browser are used to display live results from the server to spectators. If a connection to the Internet is present, live results can also be uploaded to a remote web server.

All custom hardware development is focused on the RFID stations. Each RFID station scans athletes passing over a single

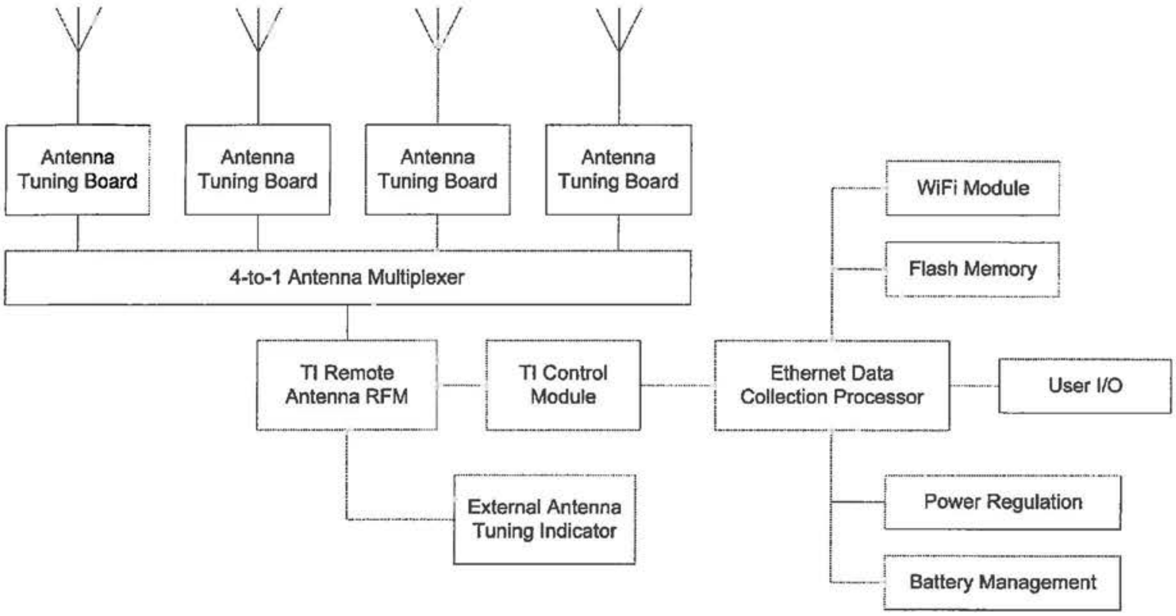

Fig. 3. A station reading, logging, and transmitting transponder identifiers consists of several key components. A Texas Instruments Series 2000 RFID reader communicates with transponders and reports the unique identifiers to an Ethernet-enabled microcontroller. This microcontroller saves the identifiers to flash memory. Identifiers stored in flash memory are then transmitted to the central reporting server.

checkpoint. For example, in a simple foot race, a single station could be placed at the finish line. In a triathlon, multiple stations could be placed so that individual times for swimming, biking, and running could be calculated.

Each RFID station will contain a number of major components (Fig 3). An off-the-shelf RS232 RFID reader module will be connected to an Ethernet microcontroller, such as the Microchip PIC18F97J60. The microcontroller will run a real-time clock and will store the identities of all scanned transponders in a flash memory chip. It will periodically upload new entries in flash to the main server running the custom service. In addition, a number of I/O components such as an LCD, keypad, and buzzer will be present to communicate with system operators and athletes.

Due to the limitations discovered in the Intersoft RFID system, a Texas Instruments-based RFID system is proposed to be integrated with the system after an initial evaluation. The intended size of an antenna mat for this application is 200 x 100 cm. This is the same size as the antenna mat marketed by ChampionChip and has been used successfully in the past for triathlons. This is too large for a single antenna. ChampionChip multiplexes their triathlon antenna mat into four antennas, which is the approach taken here. Therefore, each antenna would be 100 x 50 cm in size, which is the same size as the off-the-shelf Large Gate Antenna sold by Texas Instruments [33] and has been tested to have a range of 21 inches with the 32 mm glass transponder [27]. Four turns of 125/40AWG Litz wire will create a 100 x 50 cm antenna with an inductance of approximately $34\mu H$ [16]. Therefore, approximately 48 meters of Litz wire will be required to construct an antenna mat.

Because this situation could be handled by a single RFID reader, there is no need for the RS422/485 control module. An RS232 control module is the obvious choice, as only a voltage level-shifting chip is needed to interface the RFID reader with the UART on the application-specific microcontroller. In order to handle the loose tolerances and variations of the construction for each custom-built antenna, a Remote Antenna RFM will be selected. A four-channel antenna multiplexer along with four antenna tuning boards will complete the RFID system.

VI. Evaluation

A number of existing RFID timing systems are compared in Table II with the system described in this paper. Two of these systems, ChampionChip and RFID Race Timing Systems, also use the Texas Instruments low-frequency RFID system. The proposed system, especially if future work in automatic tuning and wireless is successfully carried out, compares favorably with these other TIRIS-based systems in both features and cost. ChampionChip, the first major chip timing company started in 1994. ChampionChip hardware inter-connectivity is poor when compared to all other systems. Both of these existing TIRIS systems require the user to manually tune the antennas to resonance. All TIRIS-based timing systems, including the proposed system, cannot handle multiple transponders over a single antenna due to limitations of the TIRIS system itself. However, these systems still handle the majority of collision cases gracefully, because they successfully read the closest transponder. Therefore, two athletes passing over the same antenna will most likely be processed. Collisions will not be a problem for many small-scale events. Unlike the previous two companies, IPICO Sports utilizes a dual-frequency system. A low frequency magnetic

TABLE II
COMPETITIVE FEATURE COMPARISON

Feature	Proposed System	ChampionChip [5]	RFID Timing [7]	IPICO Sports [6]	AMBit [8]
RFID Frequency	134 kHz (TIRIS)	134 kHz (TIRIS)	134 kHz (TIRIS)	125 kHz / 6.8 MHz	
Passive or Active	Passive	Passive	Passive	Passive	Active
Mux'ed Antennas	Yes	Yes	Yes	Yes	N/A
Automatic Tuning	Future	No	No	Yes	N/A
Anti-collision	No	No	No	Yes	Yes
Ethernet	Yes	No [34]	Yes	Yes	Yes
Wireless	Future	Cellular [34]	No	WiFi optional	No
Logging Memory	Nonvolatile	Yes	Volatile	Yes	Yes
Live Server	Yes	No	Yes	Yes	No
Open Source	Yes	No	No	No	No
Station Cost[1]	$1,540[3]	$11,900 [6]	$13,000 [4]	$13,000 [6]	$6,250 [6]
Transponder Cost[2]	$4.35	$20.00	$5.50	$3.00	$86

[1]A station handles a single four-antenna checkpoint.
[2]Transponder costs are estimated based on a purchase of 1,000 units.
[3]Parts-only estimate. Does not include assembly.

field is used to constantly energize transponders. When an IPICO Sports transponder has been energized, it transmits a unique identifier on a high frequency. IPICO Sports has included good connectivity features with their system. AMBIT offers the ChipX system, which uses active transponders. The primary advantage of active transponders is that the antennas are simple and easy to deploy.

RFID Race Timing Systems offers modern Ethernet connectivity and includes Racetec, a SQL-based database and reporting solution. IPICO Sports also offers timing software. Other timing systems require the user to purchase 3rd-party software.

The biggest strength of the proposed system is the combination of inexpensive hardware, powerful software, an open design, and a competitive feature set. The hardware costs are an order of magnitude less than other passive stations (see Tables II and III). The powerful software and open source design of both hardware and software means that others can easily extend the system with new hardware and software not previously envisioned by the original system designers. The competitive feature set combined with low cost create an initially high level of desirability, while the open design will pay off over time as others add to it.

TABLE III
PARTS COST ESTIMATE

RFID	*$ 1,130*	
Series 2000 control module		$ 275
Series 2000 RFM		275
Series 2000 multiplexer		220
Series 2000 tuning boards		260
Antenna mat		100
Main system	*160*	
Ethernet processor		20
Power regulation/monitoring		25
Character LCD		30
Keypad		20
LEDs		15
Misc. I/O		20
Printed circuit board		30
Batteries	*100*	
Enclosure	*150*	
Total	***$ 1540***	

VII. FUTURE WORK

As described now, the Texas Instruments reader relies on manual tuning. This has two implications. First, the user must manually ensure that each individual antenna is tuned properly when setting up at a new location. This is a major inconvenience and requires external tuning equipment. Second, because each antenna in the mat may differ in inductance, each antenna must be individually tuned. Therefore, a tuning board is required for each antenna.

Texas Instruments provides a small tool known as the Antenna Tuning Indicator (ATI) [35]. When plugged into an RFM, it indicates whether capacitance/inductance on the tuning board needs to be added or removed to bring the system into resonance. It is intended to aid the user in manually tuning the Remote Antenna RFM.

A custom tuning board could be designed and used. This tuning board would remove the variable inductor, a mechanical device, and replace it with more capacitors to ensure that the possibility of fine-grained adjustments remains. A series of low-resistance solid state relays could then be used to electronically and rapidly switch capacitors in and out of the system. This new tuning board would enable a control computer to quickly and automatically add and remove the capacitance in the system that was previously manually adjusted by a user via jumpers. If the same control computer also controls the multiplexer, then the capacitances for each antenna can be automatically recalled and applied during multiplexing operations. Therefore, the number of required tuning boards would be reduced from four to one. If the control computer were to implement the same functionality as the ATI, then automatic tuning would be a trivial feature to add. The additional tuning features would likely save money over the existing proposed solution of multiple tuning boards from Texas Instruments.

The hardware, as it exists now, uses a wired Ethernet configuration. It is relatively easy to add an off-the-shelf serial-to-WiFi module to add wireless capabilities to a future revision of the hardware and make the RFID scanning station truly portable. To avoid wasting power, the main microcontroller can use whatever link was available to perform uploads and leave the other link powered down. If that link were to go down, it would attempt to transmit on both links until a working link was found. This adds redundancy to the overall topology. As an example, a serial-to-WiFi module from Quatech adds approximately $145 to the system cost [36].

As an alternative to portability, Power over Ethernet (PoE) functionality can be added relatively easily. This is an ideal way to handle long race times or permanent installations. The battery would not be used unless Ethernet connectivity was lost. Unfortunately, the existing PoE standard, IEEE 802.3af, only provides for 13 watts of power [37]. This will most likely not be enough to drive a Texas Instruments RFID RFM at levels capable of reaching the desired read range. The upcoming PoE standard, IEEE 802.3at, should handle the task by providing up to 56 watts of power.

VIII. Conclusion

RFID-based timing systems offer a good balance between accuracy, precision, cost, and ease-of-use. They are unmatched in their level of automation and are highly desirable for races with hundreds to thousands of participants. By creating an RFID timing system that costs an order of magnitude less than competing systems, RFID equipment ownership will be accessible to smaller athletic events.

Two RFID readers were studied for use in an open source, well-documented design of a timing station. A low-cost reader was tested and is not suitable for this application. A new design using a high-cost reader is therefore proposed. This new design would still cost far less than commercial sports timing systems. No other problems with the timing station design are forseen. This open design will enable others to add new features and allow events to customize the software for their particular requirements. The system will be easily scaled to an event of any size.

References

[1] "Best times championchip tennessee, inc." 2002. [Online]. Available: http://www.besttimescct.com/

[2] "Event tech." [Online]. Available: http://www.event-tech.com

[3] "Lynx system developers, inc." 2004. [Online]. Available: http://www.finishlynx.com

[4] "Accuchip timing," 2007. [Online]. Available: http://www.accuchiptiming.com

[5] "Championchip world." [Online]. Available: http://www.championchip.com

[6] "Ipico sports," 2007. [Online]. Available: http://www.ipicosports.com

[7] "Rfid race timing systems." [Online]. Available: http://www.rfidtiming.com

[8] "Amb identification and timing." [Online]. Available: http://www.amb-it.com

[9] H. Cho and Y. Baek, "Design and implementation of an active rfid system platform," *saint-w*, vol. 0, pp. 80–83, 2006.

[10] D. Paret, "Technical state of art of "radio frequency identification – rfid" and implications regarding standardization, regulations, human exposure, privacy," in *sOc-EUSAI '05: Proceedings of the 2005 joint conference on Smart objects and ambient intelligence*. New York, NY, USA: ACM, 2005, pp. 9–11.

[11] . Liu and . Yao, "Design of a rfid transponder for application on secutiry," *itng*, vol. 00, pp. 945–946, 2007.

[12] R. Morales-Ramos, J. A. Montiel-Nelson, R. Berenguer, and A. Garcia-Alonso, "Voltage sensors for supply capacitor in passive uhf rfid transponders," *dsd*, vol. 0, pp. 625–629, 2006.

[13] H. Yan, H. jianyum, L. Qiang, and M. Hao, "Design of low-power baseband-processor for rfid tag," *saint-w*, vol. 0, pp. 60–63, 2006.

[14] T. I. Inc., *Antenna Reference Guide*, November 1996. [Online]. Available: http://focus.ti.com/lit/ug/scbu025/scbu025.pdf

[15] K. V. S. Rao, P. V. Nikitin, and S. F. Lam, "Impedance matching concepts in rfid transponder design," *autoid*, vol. 0, pp. 39–42, 2005.

[16] P. Youbok Lee, *Antenna Circuit Design for RFID Applications*, Microchip Technology Inc., 2003. [Online]. Available: http://ww1.microchip.com/downloads/en/AppNotes/00710c.pdf

[17] K. Finkenzeller, *RFID Handbook: Fundamentals and Applications in Contactless Smart Cards and Identification*, second edition ed., R. Waddington, Ed. John Wiley and Sons, 2003.

[18] "Digi-key catalog t081," January - April 2008.

[19] *Eco-Line Low-Frequency 32mm Glass Transponder*, Texas Instruments Inc., June 2001. [Online]. Available: http://focus.ti.com/lit/ds/symlink/ri-trp-re2b-01.pdf

[20] *32-mm Glass Transponder Eco-Line Read Only, Read/Write Reference Guide*, Texas Instruments Inc., June 2001. [Online]. Available: http://focus.ti.com/lit/ug/scbu017/scbu017.pdf

[21] *TRR01OEM-HDX*, Intersoft Corp., December 2007. [Online]. Available: http://www.intersoft-us.com/dnload/trro1oem.pdf

[22] *TR-RO1-oem*, Intersoft Corp., April 2005. [Online]. Available: http://www.intersoft-us.com/dnload/trro1oem.pdf

[23] *Series 2000 Reader System, High Performance Remote Antenna-Reader Frequency Module RI-RFM-008B, Antenna Tuning Board RI-ACC-008B Reference Guide*, Texas Instruments Inc., February 2002. [Online]. Available: http://focus.ti.com/lit/ug/scbu023/scbu023.pdf

[24] *Series 2000 Micro Reader*, Texas Instruments Inc., November 2002. [Online]. Available: http://focus.ti.com/lit/ds/symlink/ri-stu-mrd1-30.pdf

[25] *LF Reader Family Product Bulletin*, Texas Instruments Inc., 2007. [Online]. Available: http://ti.com/rfid/docs/manuals/appNotes/szzt012.pdf

[26] "Article - range performance of dual band eval. kit." [Online]. Available: http://rfidusa.com/superstore/product_info.php?cPath21_39_60&products_id246

[27] "Article - range performance of the lf s-2000 reader." [Online]. Available: http://rfidusa.com/superstore/product_info.php?cPath21_39_60&products_id245

[28] *Series 2000 Reader S251B*, Texas Instruments Inc., March 2001. [Online]. Available: http://focus.ti.com/lit/ds/symlink/ri-stu-251b-01.pdf

[29] *Series 2000 Control Module*, Texas Instruments, Inc., January 2003. [Online]. Available: http://focus.ti.com/lit/ds/symlink/ri-ctl-mb2a-03.pdf

[30] *Series 2000 Mini Radio Frequency Module*, Texas Instruments Inc., November 2007. [Online]. Available: http://focus.ti.com/lit/ds/symlink/ri-rfm-003b-00.pdf

[31] *High Performance LF Radio Frequency Modules*, Texas Instruments, Inc. [Online]. Available: http://www.ti.com/rfid/docs/manuals/pdfSpecs/hpdatsh.pdf

[32] *4-channel TX/RX Multiplexer Module for TI Series 2000*, Oregon RFID. [Online]. Available: http://www.oregonrfid.biz/store/datasheets/muxboardDatasheet.pdf

[33] *Series 2000 Antennas*, Texas Instruments Inc., March 2002. [Online]. Available: http://focus.ti.com/lit/ds/symlink/ri-ant-g01e.pdf

[34] "Championchip usa." [Online]. Available: http://www.championchipusa.com

[35] *Series 2000 Antenna Tuning Indicator*, Texas Instruments Inc., September 2002. [Online]. Available: http://ti.com/rfid/docs/manuals/pdfSpecs/ri-acc-ati2.pdf

[36] *Airborne Embedded Wireless Device Server Module, Serial to 802.11b/g Wireless LAN*, Quatech, October 2006. [Online]. Available: http://ti.com/rfid/docs/manuals/pdfSpecs/ri-acc-ati2.pdf

[37] *IEEE Std. 802.3-2005, Part 3: Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access Method and Physical Layer Specifications*, 2005.

Southern Scholars Honors Program
Senior Project Proposal Information Sheet

Name James Johnston **Date** April 8, 2008

Major BS CPES

SOUTHERN
ADVENTIST UNIVERSITY

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A significant scholarly project, involving research, writing, or special performance, appropriate to the major in question, is ordinarily completed the senior year. The project is expected to be of sufficiently high quality to warrant a grade of "A" and to justify public presentation.

Under the guidance of a faculty advisor, the Senior Project should be an original work, should use primary sources when applicable, should have a table of contents and works cited page, should give convincing evidence to support a strong thesis, and should use the methods and writing style appropriate to the discipline.

<u>The completed project, to be turned in in duplicate, must be approved by the Honors Committee in consultation with the student's supervising professor four weeks prior to the last day of class for the semester the project is turned in.</u> Please include the advisor's name on the title page. The 2-3 hours of credit for this project is usually done as directed study or in a research class.

NOTE-Senior Project Proposal Due Date: The senior project proposal is due in the Honors Program Director's office two weeks after the beginning of the semester the project will be completed. The proposal should be a detailed description of the Honors Project's purpose and proposed methodology.

Keeping in mind the above senior project description, please describe in as much detail as you can the project you will undertake. Attach a separate sheet of paper.

Signature of faculty advisor [signature]

Expected date of completion ____________

NOTE: An advisor's final project approval does not guarantee that the Honors Faculty Committee will automatically approve the project. The Honors Faculty Committee has the final vote.

Approval to be signed by faculty advisor when the project is completed:

This project has been completed as planned (date) Paper April 6, 2008 Project Jan 10, 2008

This is an "A" project Yes

This project is worth 2-3 hours of credit 2 credits

Advisor's Final Signature [signature] Date: April 8, 2008

Chair, Honors Committee [signature] Date Approved: 1 May '08

Dear Advisor,

(1) Please write your <u>**final**</u> evaluation on the project on the reverse side of this page. Comment on the characteristics that make this "A" quality work.

(2) Please include a paragraph explaining your specific academic credentials for advising this Senior Project.