

Real Cornell
Final Draft
May 3, 2006

Improving a Game of Imperfections:
A Look at RFID Technology in Soccer

With adrenaline rushing, 93,000 fans screaming, and tempers flaring, the 1966 World Cup Championship game between England and West Germany had been playing for ninety minutes, and a winner remained undecided. With play in the twelfth minute of overtime and the game tied 2-2, Geoff Hurst ran up the field and took a shot on the goal. The crowd silenced. The ball nicked the crossbar and bounced down, on or just over the line; a defender quickly cleared the ball.



Cairos and Adidas have created a system that places microchips in balls that relays ball position information to a receiver.
<http://www.geileteile.net>

The referee was unsure if the ball had crossed the line for a goal. Tofik Bakhranov, the ruling linesman, rushed over and in the heat of the moment, ruled the shot a goal. The shot left England in glory, Germany in dismay and four hundred million television viewers in endless debate.

For almost thirty-five years, controversy reigned over whether the ball completely crossed the goal line, FIFA's (Federation Internationale de Football Association) official definition of a goal. However, in recent years, new image processing has shown that the ball did *not* cross the goal line entirely, but this information was too late.

This is not the only example of a controversial goal call in soccer. Two years ago, in an English Football Association (FA) Cup game between Watford and Chelsea, the referee was again unsighted, and a shot in the fifth minute was left to be ruled by a linesman. Heidar Helguson of Watford headed the ball into the crossbar of the goal, causing it to bounce directly downward. The shot was ruled a goal, and the game ended as a tie. Television replays examined after the game clearly showed that the ball did not cross the goal line, but the goal still stood.

Soccer is one professional sport that does not use instant replay. Combined with video image processing, it could be implemented to eliminate goal controversies; however, FIFA believes that the use of these types of technology would slow the pace of the game and ruin the energy onto which fans around the world grasp. As John Baker, the head referee for the English FA said in an interview with National Public Radio, “Part of the appeal of soccer is that the ball is in constant motion. If referees were constantly interrupting the game for a view from the stands, the players, spectators and managers would get upset.” In the case of the 1966 World Cup game, numerous cameras would have had to be placed around the field to record the action. Then, a very large amount of data would need to be analyzed to determine the exact location of the ball as it neared the goal.

In response to FIFA’s concern of not losing the exhilaration that soccer provides while still using technology to clarify goals like in the 1966 World Cup Final, Adidas-Salomon AG, Cairos Technologies AG, and the Fraunhofer Institute have developed an RFID microchip system. This active RFID system consists of a microchip located in the core of the ball along with ten antennas positioned around the field. The tracking system designed by Cairos offers significant advantages over video image processing. Radio-based systems can use a very small amount of data to accurately estimate the distance between objects. This means data can be processed in real-time, and the occurrence and order of predefined significant events such as goals can be easily determined. These antennas provide a precise position of the ball.

The ability to determine the position of the ball would have helped linesman Tofik Bakhramov instantly make the right call. Even still, there has been controversy over the use of RFID technology in soccer. Tim Wheaton of Harvard Athletics puts it

“I am in favor of any technology that aids the referees in getting calls correct. If it is tested (presumably at a youth world cup) and deemed practical in the heat of competition, I am all for it,”

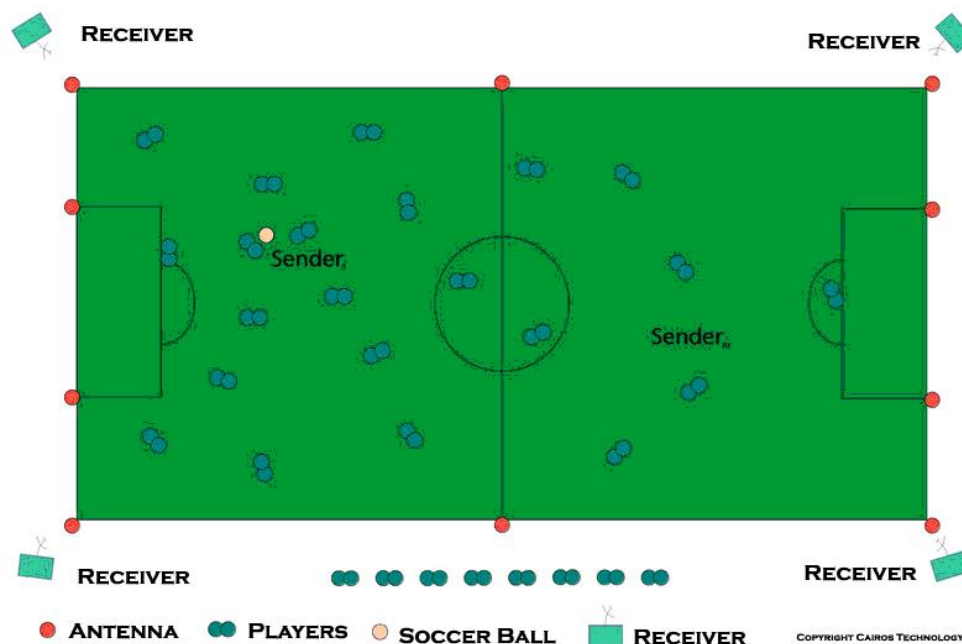
~Bryan Scales, Cornell University Men’s Soccer Coach

plainly, “Generally speaking I like the human nature of sports. Referees decisions are a part of that. I do not mind when they ‘get one wrong.’” It is the fast-paced, never stopping ball movement that allows emotions to grow and fans to react to the split-second calls. On the other hand, some people feel that this technology would be beneficial to the

game. “I am in favor of any technology that aids the referees in getting calls correct. If it is tested (presumably at a youth World Cup) and deemed practical in the heat of competition, I am all for it,” said Bryan Scales, head men’s soccer coach at Cornell University. Scales’ opinion and angle on the technology aligns with the motives of Cairos Technology and Adidas. That is, not compromising the intensity and speed of soccer, but giving aid to referees in making the right calls.

Technical Specs

Combining current RFID technology with triangulation techniques (the use of three distance measurements to determine a single location), Cairos was able to develop a way to locate the ball and the players in real time anywhere within the soccer field. Cairos’ system was designed and developed especially for use in extremely fast paced environments. The system tracks objects through RFID chips placed within the play object and the shin guards of the players. Signals are transmitted to several antennas mounted around the field by the chips. Every time a measurement is taken, signals that identify the objects are sent out from each of the chips, and the reception time of the



The field would have six antenna placed around the perimeter and one receiver in each corner of the field. Senders or RFID chips would be located in the ball and in the shin guards of all the players.
<http://www.cairos.com>

signal to the antennas is synchronized. As a result, the position is determined. When a striker takes a shot toward the goal, a watch worn by the referee would vibrate as the ball approached the goal line. The watch would then flash “GOAL” if the ball fully crossed the goal line.

According to Cairos, the system uses active RFID tags that function in the 2.4 GHz ISM (industrial scientific and medical) band. The high frequency gives their tags a fast data transfer rate and a large transmission range. Since the ISM band is internationally license free, the system can be implemented worldwide. Cairos’ system has a range of 300m by 300m and can process approximately 100,000 measurements per second. The accuracy of the system is thus within the range of one to two centimeters, even if the object is moving with a speed of up to 140 km/h. The size of the transmitters, including the accumulator, is 2 x 2 x .5 cm or approximately the size of a penny; this makes the physical implantation of the chips relatively easy.ⁱ

Controversies due to uncertainties have been a part of the world of soccer since the 1800’s. Questionable referee calls have generated anger, hostility and ensuing conflicts that have cost the lives of players, referees and fans worldwide. In the past decade, over one hundred fans have been injured or died due to conflicts and riots. There have also been numerous death threats to referees, including one during the current European Cup. To eliminate potential uncertainties within the system that could cause additional controversies, Cairos has purposefully built redundancies into their system. While most triangulation systems require three reception points, Cairos’ system requires four antennas to determine a 3D position. Since a lot of interference can occur in radio-based systems, Cairos’ system uses at least six of its ten antennas instead of the necessary four. In reports about this technology, FIFA repeatedly states their main concern about using a ball with an implanted chip is its reliability and accuracy. The built-in redundancy addresses potential antenna unit failures and eliminates concerns about further controversies resulting from an error with the technology. A greater number of antennas increase the quality and validity of the signal received. Interferences by other systems functioning in the 2.4 GHz ISM band have been explicitly taken into account throughout development and have not yet been detected; however, this system has interfered with numerous other wireless systems in the area. Current testing is being done to contain the

radio waves to prevent interference with other systems, while still maintaining the system's accuracy.

Challenges of the Microchip in the Ball

The technology was first installed in the Franken Stadium in Nuremberg, Germany, where engineering specialists from the Fraunhofer Institute for Integrated Circuits were in charge of performing the initial testing of the technology. The testing focused on the chip being placed solely in the ball. FIFA is refraining from placing the chips in shin guards until the initial technology is tested and proven to work.

FIFA has started the process of testing the effectiveness of the technology in live game play. The system was first used in an official competition during the September 2005 Under-17 FIFA World Cup in Peru, in which four out of the five stadiums were equipped with this technology. During the tournament, the referees had to stop the game on multiple occasions to replace the ball because the chip became loose. Adidas has suspended the chip in the middle of the ball in order to survive the hard kicks and fast acceleration. Very little information is available as to what problems occurred with the sending of the signal from the ball to the referee's watch. However, there are few, if any, complaints about disruptions due to issues other than a loose chip. After the Under-17 World Cup, Sir Bobby Carlton, an English player in the 1966 World Cup game, said, "I'd like to see [the technology become widespread]. It's either a goal or it's not, and at least we'd know."



The microchip in the ball relays a signal to a central computer which then sends a message to a watch worn by a referee indicating a goal.
<http://www.eszak.index.hu>

FIFA is being very tight-lipped about the specific successes and failures of the initial tests, but officials have determined that the technology will still require some adjustments before full implementation. The scheduled testing of the technology at the Club World Championship in Japan in December 2005 was cancelled, and FIFA has decided to wait until next year for further testing. FIFA has stated that their

objective is to achieve 100% system reliability. Therefore, the chip will not be used during the World Cup in June 2006.

Once the technology has satisfied FIFA's standard for implementation, FIFA is going to have to produce the time and resources required to equip the various stadiums with the system in order for it to be used in play. Despite all official fields being the same dimensions, the specific details surrounding the field change considerably. The bench locations and field-side billboards may be too close to the edge of the field for the current antennas to take accurate readings. In order to install the system in these stadiums, new ways to mount the antennas would have to be determined. Players will also want to be able to practice with the system in order to determine what will be called a goal before using it in games with stakes as high as the World Cup.

The system has the ability to do more than simply eliminate the controversial goals through the recording of players' statistics and movement; there has been concern by some coaches and players that this information can be misused. Current technology allows players' movements to be captured on video, but Cairo's system allows for more precise information. For example, a microchip in the shin guard of a player will record strategic ball movement and specific player locations during plays. Other teams may then review this information in order to improve their own game. "Chips in shin guards seem different to me," says Wheaton, "They could be a great asset on the training/coaching side if you could set up software to track the movements of players (like a moving x's and o's sheet.)"



This technology can be implemented not only in the soccer ball but also in players' shin guards. (Photo: Mariana Bazo, Reuters) <http://www.nrk.no/sport/fotball/5105272.html>

Another concern FIFA has is the cost of implementing the RFID systems at stadiums around the world. FIFA first plans to use Cairo's system only at major competitions like the World Cup and the European Cup. The remembered controversies like those of 1966 and 2004 would be the first to be eliminated. However, FIFA President Sepp Blatter is concerned that

"no schism develops between rich and poor" saying that "football must remain the people's game."ⁱⁱ Croquet and polo have always been sports played by the upper class, while soccer is famous for the pick-up games on dirt fields in developing countries. It is

the members of these countries, along with working class Europeans that give soccer its fan base. The cost of the technology would need to be affordable so that even the poorer countries can install the technology. Once the cost decreases, FIFA plans to implement the system at stadiums around the world where any official competition takes place.

Other Applications

RFID technology is already in place in other sports as a way to simplify the gathering of statistics. One basic example is the attaching of chips to marathon runners in order to get more exact finishing times. During the 2003 Boston Marathon, runners were equipped with the ChampionChip®, a tiny transponder that relayed a message to a receiving antenna that recorded players' times at certain locations. The chip enabled everyone to start at one moment and each runner to have a unique log of running times.

While the use of Cairos' system has many advantages in soccer, it also has the potential to be used in countless other sports such as ski jumping and American football. This technology can sustain high winds, cold weather, and harsh conditions. Alpine sports, ski jumping and Nordic skiing have not been able to take advantage of any tracking technology thus far, but thanks to a transmitter located on the skis, coaches and skiers will be able to use Cairos' system to determine a skier's exact position.ⁱⁱⁱ Athletes for the first time will be able to monitor exact ski paths during practice runs, and coaches can later analyze these practice runs and find the optimal route for a Nordic skier to take. The National Football League (NFL) would be able to use Cairos' system in much the same way as soccer: to send information about ball position and line decisions to the referee. This would be in addition to the instant replay technology already in use.

While RFID was developed in the early 1900's, the soccer ball chip is a novel application of this technology. Cairos has proven the potential of using RFID in soccer. Cairos has a strong vision for the boundaries the technology can push, without losing the integrity of the sport. However, critics may argue that the introduction of the technology in soccer may hinder the game by eliminating the human role in officiating. This view is echoed by Coach Swanson who points out that "History has shown over the years even

with modern technology we still do not always get it right. Adversity is part of the game whether that adversity is bad weather, a bad pitch or in some cases a missed call. Without this adversity we tend to lose some of the great benefits which sports can provide no matter what the level.”

Whatever the final place is for the RFID system developed by Cairos Technology, Adidas-Salomon and the Fraunhofer Institute, the idea of placing a microchip into a ball to track its position is innovative and unique. People will presumably forever be striving for perfection, especially in competitive fields such as sports. While Geoff Hurst’s goal and England’s World Cup victory will remain in the history books, the soccer ball chip provides hope that controversial goals will be the thing of the past.



GOOAAAAL!!!

<http://www.rediff.com/sports/2005/sep/15ball.htm>

ⁱ Cairos Technologies. <http://www.cairos.com>

ⁱⁱ Guardian Unlimited “Smart Chip Coming to Football’s Aid”

ⁱⁱⁱ Cairos Technology. *Cairos Technology in Ski Jumping*. January 2006
< <http://www.cairos.com/sports/skispringen.php>>