

Establishment of the University of Pittsburgh RFID Center of Excellence

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Abstract—This is the history of the establishment of the **RFID Center of Excellence at the University of Pittsburgh including the original conceptual framework and the milestones that made it a natural consequence of previous research and development.**

Index Terms—RFID, Center of Excellence, energy harvesting, backscatter

I. INTRODUCTION

THE origin of the technology base that established the Radio Frequency Identification (RFID) Center of Excellence at the University of Pittsburgh can be traced to a project to find lost hearing aids. The concept was to place some small device in the molded portion of the hearing aid requiring no battery and no connection to the battery or electronics of the hearing aid. This device was to be powered by continuous wave (CW) radio frequency (RF) energy and identified by a second transmitted RF wave response from the device to be identified by a receiver. The concept is similar in many ways to classical backscatter RFID except that the device response signal is from an active transmitter at a frequency different from that of the energizing RF wave.

The basic device technology involves harvesting the incoming RF energy and converting it to direct current (DC). This conversion makes it possible to operate essentially any type of electronic circuitry on the device providing ample energy can be harvested. Thus, the original hearing aid device became a platform technology for remotely powered sensor devices, i.e., the power plant for devices with the limiting instantiation on the order of smart dust. The technological goal is thus to reduce size while not severely compromising available power. In essence, the entire sensor and powering circuitry are to be fabricated on a single silicon chip. Figure 1 is an early version of a single chip antenna solution.

At one point in this research, collaboration was established between supply chain researchers in Industrial Engineering (IE) and RF technology researchers in Electrical Engineering (EE) in order to respond to a DARPA RFP to establish a set of test procedures for evaluating commercial RFID tags and readers. The contract was awarded, and the results led to the

confirmation of 915 MHz as a standard UHF frequency. Eleven commercially available RFID readers and tags were shipped to Pitt and tested for performance and characterization of potential jamming scenarios. Following the successful implementation of the test procedures, the EE researchers returned to antenna design, energy harvesting and RF communications.

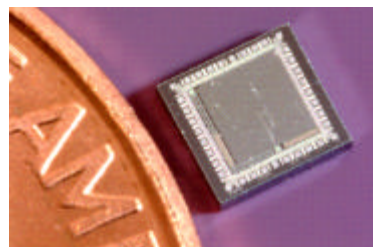


Figure 1. PENI Tag Antenna.

During the period of collaboration, the research group followed the industry developments in RFID. At one point, corporate RFID researchers became interested in the energy harvesting and antenna work by the Pitt team. The ability to fabricate a complete RFID device on a single chip had the potential of a significant economic impact due to the elimination of tag (antenna and chip) fabrication, i.e., "No Assembly Required." This attention meant over 100 companies visiting the University of Pittsburgh in a relatively short time including the major players from both users and vendors of RFID.

The Pitt team considered a redirection into classical backscatter RFID but decided in favor of continuing research in energy harvesting with extensions to very low power protocols for communication. The technology developed resulted in a number of patents issued and pending. This IP has provided the basis for three spin off companies that licensed various elements of the University intellectual property.

Although not focusing on supply chain aspects of RFID, the continued outside interest in the Pitt research led to numerous additional companies visiting the research laboratories to learn more about the technologies being investigated and their relationship to classical backscatter RFID.

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II. BACKGROUND

A. Collaboration with Industry

The initial RFID related research funding came from a number of sources outside the University some of which were collaborative organizations with conditions on the handling of intellectual property (IP). In particular, the IP was to be shared by the member organizations of the collaborative through non-exclusive licenses. As IP was developed, attempts to license this to start-up companies reinforced the obvious conclusion that private funding organizations rely on the candidate businesses having the exclusive rights to the base IP supporting the fundamental technology on which the company is based. It was clear that funding with non-exclusive IP rights was not viable to provide technology for spin off enterprises. This problem was solved through internal University funding to establish the basic art by which the Center would eventually operate. Although it was clear that the research group was operating with a specific focus on RFID, no Center was in place at that time.

B. Complications in Licensing

The ability to license technology to start-up companies is one of the goals of technology transfer with considerable emphasis at local and national levels. In the normal context, it is assumed that what is licensed is a device, i.e., a "widget." However, when the license is on a technology or some aspect of a technology, another more complicated type of situation is encountered.

Typical term sheets have the start-up, Company X, pay normal royalties, satisfy milestones and pick up patent costs while striving to provide a business plan showing a profit, a lift in valuation, and a profitable exit strategy. In this strategy, cash is an important commodity to be conserved.

In the widget case, the University researchers move on to another widget or continue with the basic research. The situation involving the licensing when a technology is involved is problematic. The licensing rules are essentially the same as with the widget, but the University follow-up research in general is not. At the point of licensing to Company X, there is some clear means by which the company will utilize the technology for a profit. However, a single technology may have many facets and the University continues research in the general technology area including the disclosure of new aspects including advances possibly in the originally licensed technology.

This leads to a difficult situation for Company X. If they license all the advances in the technology, they are unduly burdened with patent costs and potentially a loss of focus. If Company X does not continue to keep up with the licenses, there is a chance the new art will be licensed to a company that immediately becomes a competitor with newer technology as a commercial advantage.

To avoid the situation of the University competing with the licensee, it is necessary to be able to provide innovative concepts to address related aspects without direct

competition with the spin-off(s). This is the path that has been chosen by the RFID Center at the University of Pittsburgh. Thus, it is important from the outset that a clear path and means of continuing research on a variety of current and non-conflicting research objectives have been recognized from the time we began thinking about an RFID Center.

III. EXISTING RFID CENTERS

The academic activity in RFID was clearly going in the direction of establishing University Centers. It appeared that the majority of these Centers had been geared to the evaluation of the placement and type of tag to be applied to a specific carton or pallet. While the University had done this type of work as a part of the early DARPA contract for hazardous materials, this was not the direction in which we were heading. As indicated previously, that particular contract was a joint effort between Industrial Engineering (supply chain orientation) and Electrical Engineering (reader to tag powering, communication and integrity).

Based on the current directions and changes in personnel, it was decided to follow the more hardware oriented (EE) aspects of RFID. Thus, based on the concept used by consumer utilities, we adopted the slogan - "The Last Mile" - as the focus of our research meaning all aspects of the interactions between the reader and the tag.

IV. THE EARLY FOUNDATION

It was clear that the University of Pittsburgh was receiving a considerable amount of attention in the RFID space for a variety of reasons. One such indication was the appearance in the media of suggestions that Pitt was among the top three in the world sharing that honor with MIT and Cambridge in the UK. While we had numerous visits from companies previously, it appeared that this number was increasing weekly. It was at this point that it was decided that the formation of a Center was in order.

A. Technology

While RFID is obviously important today and possibly for many years to come, the need for a research center of excellence in support of such an application came with issues of long term sustainability. Thus, the Center is based on fundamental scientific and engineering research in the powering of and communication with small autonomous devices that derive their operating power from RF energy normally supplied through the air.

B. Focus

The continuing large number of visitors and supply chain opportunities were significant in the decision to expand the focus of research to include all facets of RFID. Supply chain management and characterization were included with considerable research emphasis in this area - particularly in mathematically optimizing read rates.

C. Industry Interaction

One of the bullet points of the University of Pittsburgh Mission is "Partner in Regional Development." This partnership includes helping regional development through forming new industry which is a key goal of the RFID Center - provide a source of technology to aid industry in the advancement of RFID and related technologies for economic development.

V. ESTABLISHING THE RFID CENTER OF EXCELLENCE

Given the above background and foundation, it was decided in the Summer of 2005 to form the University of Pittsburgh RFID Center of Excellence to continue and expand the research and development of RFID and related technologies.

A. Strategic Plan

The ability to maintain a preeminent position in any field of technological research requires knowledge of the needs and competition especially in a rapidly changing field such as RFID. For example, as an illustration, an *initial* survey (a simple Google search) was performed using only "RFID". The search was then refined by using the term "passive" and then with "backscatter" along with several additional refinements to populate a tree with the root RFID. This tree (picture) was then replicated reflecting "University" activity, and then issued "Patents." Based on these trees, the areas that were the least populated were analyzed to provide opportunity areas for future Center research.

B. Infrastructure Investment

There are two primary types of capital investment that translate into infrastructure; (1) human, and (2) equipment. As a research University, the mentoring and graduating of Ph.D. students is critical for academic reputation making the recruiting and training of Ph.D. students the top priority of the infrastructure where their dissertations provide both academic integrity and potential intellectual property that supports industry and company formation. To insure top quality Ph.D. graduates, top quality full time faculty are required. This is a must for the Pitt Center.

The equipment investment is intended to maintain a position at the cutting edge of technology requiring the latest RF analysis and characterization equipment. The goal here is the ability to analyze a reader/tag exchange while it is taking place in real time without interfering with the transmission in either direction and at the same time being a completely non-invasive test. The type of equipment here is the class of Real Time Spectrum Analyzers and Vector Signal Generators such as those produced by Tektronix, Agilent and National Instruments.

One of these configurations replicates the EPCglobal testing equipment at the MET Laboratory in Baltimore, MD.

C. Transcendent Strategies

While some centers focus on analyzing and supporting a

particular frequency range - LF, HF, or UHF; field characterization - near field or far field; tag type - active or passive; etc., all of the above are considered to be important with the focus being on the underlying technologies and our internal "applications" being on such things as rapid prototyping, non-invasive testing, antenna design and measurement. In this manner, the research of the Center will transcend any specific application and provide the mathematical and physical analysis to support technological developments in any general of application. Both physics and engineering remain the keys to academic research.

Before the Center was actually formed in 2005, one of the spin-off companies was involved in manufacturing and the other in medical devices. The manufacturing company won the 2006 Carnegie Science Center Award for Excellence in Advanced Manufacturing and Materials while only being in existence for approximately a year. That was a demonstration of the type of "Partner in Regional Development" that is being sought.

As an example of a transcendent strategy, the energy harvesting and communications opportunities in biomedicine are numerous. One project involved sensing a blink in one eye lid to cause the second eye lid to blink is important for people who lose their 7th optical nerve. Figure 2 is a photo taken during animal studies where a sensing device is in one anesthetized rat's leg and an actuator is implanted in a second anesthetized rat's leg. In the test, moving one leg causes the leg to move correspondingly on the second rat.

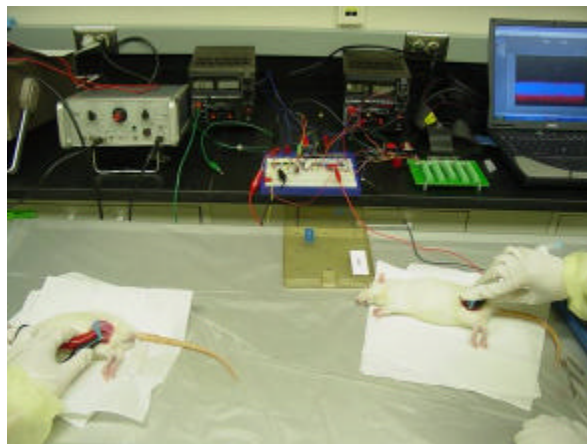


Figure 2. "Robo" Rat.

While the research suggested by this example may appear to be a long way from RFID, it is likely closer than we like to think. In any case, it is a clear example of multiple types of RFID related technologies being applied to a wide range of problems. Examples like this are the basis for involvement of medical faculty in the research of the Center.

VI. THE ESTABLISHMENT OF THE RFID CENTER

A. Announcement

The formal announcement of the establishment of the RFID Center of Excellence was held on September 30, 2006. The ceremony was held in Alumni Hall of the University of Pittsburgh and included words by the Chancellor, Provost and a number of companies that we had worked with in the early days of the research.

The indices of success are to include those of any quality academic program including publications, Ph.D. graduates and research support.

B. Current Center Operation

Prior to the center formation, the RFID research administration responsibilities were handled by the Swanson Institute for Technical Excellence in the School of Engineering. Now, as a separate Center, administration is kept to a minimum with the focus on research and working with regional industry. The "regional" has turned out to be anywhere between the Atlantic and Pacific although most recently, the Center has also become the "house" for the Southwestern Pennsylvania RFID User's Group.

The participating faculty include at least a dozen School of Engineering faculty, five from the School of Medicine and others from the School of Information Science. Since beginning operation slightly over a year ago, we have produced one Ph.D. graduate with another anticipated in a few months and five additional candidates.

We currently have 22 active projects in varying degrees of activity with roughly 15 journal publications and numerous invention disclosures in the one year period.

In the area of intellectual property, we have 6 issued patents, 21 published applications pending, and on the order of 15 newer pending applications.

Two generous alumni have funded laboratories, and we have been given notice of one major industrial contribution of equipment and are expecting to close on a second in the near future.

The Center sponsored a booth at the RFID Journal Live in Las Vegas in 2006 which was most successful and turned out to be a great investment in terms of new activities that continue to grow seven months later.

C. Summary

The University of Pittsburgh RFID Center Of Excellence does not fit the classical "slap and ship" mold. While those functions are important to the majority of potential shippers, the major problems that transcend traditional RFID can be expected to be solved by the vendors and the Fortune 100 suppliers. Our goal is to focus on the later while helping the former to the extent possible.



Marlin H. Mickle (F'97) received the B.S.E.E., M.S.E.E. and Ph.D. degrees from the University of Pittsburgh in 1961, '63 and '67 respectively. Currently, the research of Professor Mickle is focused on RFID and the related technologies focused on the autonomous device characterization.

He has held engineering positions with Westinghouse and IBM as well as Program Director at the National Science Foundation.

Professor Mickle was the 1988 recipient of the Systems Research and Cybernetics Award from International Institute for Advanced Studies in Systems Research and Cybernetics; the Carnegie Science Center 2005 Award for Excellence in Corporate Innovation; and University Innovator Awards in 2005 and 2006.