Matthew S. Reynolds, Ph.D.

CONTACT INFORMATION

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RESEARCH INTERESTS

Circuit, system, sensor, and actuator design, especially the physical layer of ultra low power and low cost RFID and sensor network systems.

EDUCATION

Massachusetts Institute of Technology, Cambridge, Massachusetts USA

Ph.D., MIT Media Lab, February 2003

Dissertation Topic: "Low frequency indoor radiopositioning"
Advisor: Prof. Neil A. Gershenfeld (MIT)
Committee: Prof. Joseph Paradiso (MIT), Dr. Richard Greenspan (Draper Laboratory)

M.Eng., Electrical Engineering and Computer Science, February 1999.
S.B., Electrical Engineering and Computer Science, February 1998.

HONORS AND AWARDS

Best Paper Award, ACM Conference on Pervasive Computing, 2008.
Best Paper Award, ACM Conference on Ubiquitous Computing, 2007.
Motorola Fellow, MIT Media Lab, 1997 - 2002.
First place, AUVSI International Autonomous Underwater Vehicles Competition, 1998, 1999.
Interactive artwork, *White Noise, White Light* (with Meejin Yoon) selected by the City of Athens for the 2004 Olympics.
Interactive artwork, *Defensible Dress* (with Meejin Yoon) installation at Los Angeles Museum of Contemporary Art, 11/06-3/07.

PROFESSIONAL EXPERIENCE

Duke University, Durham, North Carolina USA

Assistant Professor, Department of Electrical and Computer Engineering **1/2008 - present**
Member of the Signal Processing, Microsystems, and Computer Engineering TIGs. Research program includes projects in RFID, distributed sensors, and robotics.

Ph.D. Students Advised
Stewart Thomas, ECE, Duke University **8/2008 - present**
Travis Deyle, ECE, Georgia Tech **7/2007- present**

Special Problems Students
Vidhan Srivastava, MEMP, Duke University **9/2007 - 6/2008**
Gagan Mallik, MSCS, Georgia Tech **9/2007 - 12/2007**

Georgia Institute of Technology, Atlanta, Georgia USA

Senior Research Scientist, School of Interactive Computing **3/2007 - 12/2007**
Originated a research program in RFID and distributed sensors, including projects in healthcare robotics (collaboration with Georgia Tech's Health Systems Institute), indoor radiolocation, and human powered computing. At Georgia Tech, technical supervisor of a team including three Ph.D. students, one postdoc, one engineer.

ThingMagic Inc, Cambridge, Massachusetts USA

Co-Founder, Chief Technology Officer **2001 - 2007**
Consultant, Technology Adviser **2007 - present**
Co-founder of ThingMagic, a leading provider of RFID reader products and systems, as well as

custom engineering and consulting services, to numerous Fortune 500 companies in the retail, industrial, and medical markets. Grew the company to 38 employees through self-funding and over 60 employees by raising $21MM in equity investment. Originated the software-defined RFID technology that brought ThingMagic to a market-leading position, and built on that success through five generations of RFID products.

Technical Activities
Lead architect and engineering supervisor of a growing engineering team. Directed numerous software-defined radio projects from concept through prototype and volume production, and managed FCC and UL certifications. Lead architect of signal processing systems including high speed direct baseband sampling on the Intel XScale (ARM), TI DSP family, 68000, MSP430, and PIC microprocessors. Lead architect and designer of RF and microwave systems including receivers, transmitters, RFID readers, sensor tags, and other analog and mixed signal systems at frequencies from 125KHz to 2.4GHz. Architect of RFID ASIC efforts including BiCMOS mixed-signal and RFIC design.

Professional Activities
Represented ThingMagic in RFID industry standards organizations such as the Auto-ID Center and EPC Global, most recently as Co-Chair of an EPC Global Action Group. Author of technical reports for those audiences. Invited speaker on RFID technology at IEEE / ACM and Auto-ID Center symposia.

Intellectual Property Activities
Performed intellectual property analysis, assisted IP counsel with the preparation of patent applications, legal opinions, and IP strategy. Named inventor on 2 issued and 12 pending US patent applications in the field of RFID and sensor systems.

Massachusetts Institute of Technology, Cambridge, Massachusetts USA

Research Assistant, MIT Media Lab **1997 - 2003**
Extensive analog and mixed-signal design work, as well as theoretical and practical work toward the design and implementation of a low frequency radio positioning system for indoor use. Work experience includes RF design, digital signal processing, microcontroller design, and mathematical models of signal propagation. Collaborations with several corporate research sponsors, including Motorola, LEGO, and United Technologies. In collaboration with Yale University and the Boston Museum of Science, designed and built satellite-uplinked weather probes that have been installed at the south summit of Mt. Everest and the Embree Glacier in Antarctica. Designed the inertial navigation system for MIT's ORCA autonomous submarine. Numerous collaborations to bring technology to artists. Supervisor of three undergraduate student researchers.

Industry Tutor, MIT 6.002x **2004**
Industry tutor for a group of five students in Prof. Gerry Sussman's experimental version of MIT's 6.002, Circuits and Electronics. This version of the standard class is focused on small group tutorials in which students work with their tutor to complete problem sets and laboratory exercises.

TA and Guest Lecturer, MIT MAS863 **1998 - 2003**
Responsible for microcontroller design and RF communication techniques classes for Prof. Neil Gershenfeld's MAS863 graduate class over a period of four years. Developed lab exercises for these classes which culminated with student digital transmitter and receiver projects. Guided students through the construction and evaluation of those projects.

Teaching Assistant and Organizer, MIT 6.270 **1995 - 1997**
Experienced assistance for students during MIT's famous LEGO robotics course. Lectured on multiprocessing and reactive control strategies for robotics. Planned and executed 1996 and 1997 6.270 courses and competitions.

UROP Student, MIT Media Lab **1995 - 1997**

Designed and constructed miniature Doppler and pulse radars for imaging and communication using phased micropatch antennas, microstrip circuits, MMICs, and discrete components at S and X band. Digital signal processing design. Design and implementation of time and frequency domain NMR spectrometer subsystems and 100W power amplifier for pulsed NMR research at HF. Design and implementation of VLF network analyzer for detection of magnetostrictive resonators, as well as scalar network analyzer for HF resonators. General RF and microwave engineering.

Private Consulting Activities

Motorola Inc, San Jose, CA USA

Consultant, Worldwide Smartcard Solutions Division **1999 - 2001**

Member of a small team working on the development of a novel low-cost radio frequency identification (RFID) technology. Responsible for the design and analysis of anticollision algorithms and related tag and reader analog and digital hardware. Created emulation hardware to test these algorithms. Wrote internal technical reports to document and communicate these design contributions to the development team.

LEGO Futura ApS, Boston, Massachusetts USA

Consultant **January, June 1998**

Designed and implemented interesting and unusual educational toys incorporating optical and electric field sensing, digital signal processing, RF telemetry, and computer graphics. Also carried technology transfer responsibilities to extend ideas developed at the MIT Media Lab into low-cost versions for LEGO's commercial products.

Refereed Publications

T. Deyle and M. Reynolds, "PowerPACK: A wireless power distribution system for wearable devices" in Proceedings IEEE Conference on Wearable Computing 2008, Pittsburgh, PA, pp. 91-98.

T. Deyle, C. Kemp, and M. Reynolds, "Probabilistic UHF RFID Tag Pose Estimation with Multiple Antennas and a Multipath RF Propagation Model" in Proceedings IEEE/RSJ Conference on Intelligent Robots and Systems 2008, Nice, FR, pp. 1379-1384.

T. Deyle, C. Anderson, C. Kemp, and M. Reynolds, "A Foveated Passive UHF RFID System for Mobile Manipulation" in Proceedings IEEE/RSJ Conference on Intelligent Robots and Systems 2008, Nice, FR, pp. 3711-3716.

E. Stuntebeck, S. Patel, T. Robertson, M. Reynolds, and G. Abowd, "Wideband PowerLine Positioning for Indoor Localization" in Proceedings ACM International Conference on Ubiquitous Computing 2008, Seoul, KR, pp. 94-103.

J. Yun, S. Patel, M. Reynolds, and G. Abowd, "A Quantitative Investigation of Inertial Power Harvesting for Human-powered Devices" in Proceedings ACM International Conference on Ubiquitous Computing 2008, Seoul, KR, pp. 74-83.

T. Deyle and M. Reynolds, "Surface based wireless power transmission and bidirectional communication for autonomous robot swarms" in Proceedings IEEE Conference on Robotics and Automation 2008, pp. 1036-1041.

S. Patel, M. Reynolds, G. Abowd, "Detecting Human Movement by Differential Air Pressure Sensing in HVAC System Ductwork: An Exploration in Infrastructure Mediated Sensing." in Proceedings of Pervasive 2008, Springer LNCS 5013, pp. 1-18. **Best Paper Award**.

M. Reynolds, A. Mazalek, and G. Davenport, "An acoustic position sensing system for large scale interactive displays", in Proceedings IEEE Sensors 2007, pp. 1193-1196.

A. Mazalek, M. Reynolds, and G. Davenport, "The TViews Table in the Home" in Proceedings IEEE International Workshop on Horizontal Interactive Human-Computer Systems (TABLETOP'07), 2007, pp. 52-59.

S. Patel, T. Robertson, J. Kientz, M. Reynolds, and G. Abowd, "At the flick of a switch: Detecting and classifying unique electrical events on the residential power line." in Proceedings International Conference on Ubiquitous Computing (UBICOMP 2007), Springer LNCS 4717, pp. 271-288. **Best**

Paper and Best Presentation Awards.

A. Mazalek, M. Reynolds, and G. Davenport, "TViews: An extensible architecture for developing multi-user digital media tables", in IEEE Computer Graphics & Applications, Special Issue on Interacting with Digital Tabletops, vol. 26 no. 5, 2006, pp. 47-55.

M. Reynolds, B. Schoner, J. Richards, K. Dobson, N. Gershenfeld, "An Immersive, Multi-User Musical Stage Environment", in Proceedings ACM SIGGRAPH 2001, ACM Press, NY, 2001, pp. 553-560.

E.R. Post, M. Reynolds, M. Gray, J. Paradiso, N. Gershenfeld, "Intrabody Buses for Data and Power" in Proceedings IEEE ISWC 1997, IEEE Press, 1997, pp. 52-55.

J. Paradiso, C. Abler, K. Hsiao, M. Reynolds, "The Magic Carpet: Physical Sensing for Immersive Environments" in Proceedings ACM CHI '97, Extended Abstracts, ACM Press, NY, 1997, pp. 277-278.

Technical Reports

M. Reynolds, J. Richards, S. Pathare, H. Tsai, Y. Maguire, R. Post, R. Pappu, B. Schoner. "Multi-band, Low Cost EPC Tag Reader", MIT Auto-ID Center Technical Report MIT-AUTOID-WH-012, 2002, pp. 1-24.

Theses

Reynolds. Low frequency indoor radiopositioning. PhD Thesis, MIT, February 2003.
Reynolds. A Phase Measurement Radio Positioning System for Indoor Use. M.Eng Thesis, MIT, February 1999.

Patents Issued

US7,453,363. RFID reader system incorporating antenna orientation sensing
US7,075,412. Methods and apparatus for operating a radio device

Patents Pending

US20080275326. Sensor for monitoring a condition of a patient
US60/912871. Methods and apparatus for jamming suppression in an RFID reader
US20080091345. Sub-room-level indoor location system using power line positioning
US20080018327. Methods and apparatus for RFID tag placement
US20070040689. Dynamically reconfigurable antenna for RFID label encoders/readers
US20070040687. RFID reader system incorporating antenna orientation sensing
US20070030609. Methods, devices, and systems for protecting RFID reader front ends
US20070280369. Systems and methods for active noise cancellation in an RFID tag reader
US20070001813. Multi-reader coordination in RFID system
US20070001851. Configurable, calibrated radio frequency identification tag system
US20060293018. RFID reader front end
US2003:10/448,053. Methods and apparatus for operating a radio device
US20030112972. Data carrier for the secure transmission of information and method thereof

Publication Reviewer

IEEE Transactions on Circuits and Systems I (TCAS-I)
IEEE Transactions on Automation Science and Engineering
IEEE Tabletop 2008
ACM Pervasive 2006
IEEE Body Sensor Networks 2006

Conference Organization	Program Committee, IEEE RFID 2009 Program Committee, Location and Context Awareness 2009 Program Committee, IEEE Tabletop 2008 Demonstration Chair, IEEE Symposium on Wearable Computing 2007 Program Committee, IEEE Location and Context Awareness 2007
Invited Talks	RFID Security at the Physical Layer: Securing the Tag Read Zone. Workshop on RFID Security in Theory and Practice. Lorentz Center, University of Leiden, Netherlands. March 26-28, 2008. RFID for Mobile Manipulation. WillowGarage Inc, Palo Alto, CA. December 2, 2008. The present and future of animal tracking with RFID. NSF Sponsored Workshop on Animal Tracking and Physiological Monitoring, Princeton University, 23-25 May 2007. New Developments in Embedded RFID Readers. IEEE MTT-S IMS Microwave Applications, Long Beach, CA, June 2005. The Physics of RFID. Joint Boston IEEE / ACM Meeting, Cambridge USA, May 20, 2004. The Physics of RFID. RFID Privacy Workshop, Cambridge USA, November 15, 2003. Progress in software defined RFID readers. Auto-ID Center Spring Meeting, University of Cambridge UK, June 2003. Software defined RFID readers. Auto-ID Center Fall Meeting, MIT, Cambridge USA, November 2002.
Professional Societies	Member, IEEE Microwave Theory and Techniques Society 2001- Member, Institute of Navigation 2001-