BIOGRAPHICAL SKETCH

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NAME: Vaughan, John Thomas

eRA COMMONS USER NAME (credential, e.g., agency login): Vaughan7

POSITION TITLE: Professor and Director of the Columbia Magnetic Resonance Research Center

EDUCATION/TRAINING *(Begin with baccalaureate or other initial professional education, such as nursing, include postdoctoral training and residency training if applicable. Add/delete rows as necessary.)*

INSTITUTION AND LOCATION	DEGREE *(if applicable)*	Completion Date MM/YYYY	FIELD OF STUDY
Auburn University, Auburn, AL	B.S.	1982	Biology
Auburn University, Auburn, AL	B.E.	1982	Electrical Engineering
University of Alabama at Birmingham, AL	Ph.D.	1993	Biomedical Engineering

A. Personal Statement

J. "Thomas" Vaughan was recruited to Columbia University to found the new Columbia Magnetic Resonance Research Center. This Center has made innovative use of cloud connectivity and data sharing to bring together the talent, equipment and resources from six Columbia affiliated schools and institutions and over 150 NIH sponsored investigators to further science and medicine on more impactful scales. Specifically, Columbia's Schools of Physicians and Surgeons, Engineering and Applied Sciences, and Arts and Sciences partner with the Zuckerman Mind, Brain, Behavior Institute, the New York State Psychiatric Institute, and the Nathan Kline Institute for Psychiatric Research to form the Center. Magnetic resonance imaging (MRI), magnetic resonance spectroscopy (MRS) and functional magnetic resonance imaging (fMRI) are used to noninvasively observe the human anatomy, metabolism and physiology in states of health, disease and therapeutic intervention. These powerful new research tools will be developed in Columbia's Engineering School and applied to basic research at the Zuckerman Mind, Brain, Behavior Institute, and to translational research at the Columbia University Irving Medical Center and the sister affiliated New York State sponsored Psychiatric Research Institutes. Dr. Vaughan was recruited from the University of Minnesota where he held the Quist-Henline Chair in Biomedical Research, and was Director of Engineering at the Center for Magnetic Resonance Research, with appointments in Radiology, Biomedical Engineering and Electrical Engineering. Vaughan has helped to establish and build MR Research Centers at UT Southwestern, U. Alabama at Birmingham, Massachusetts General Hospital and Harvard, U. Minnesota, and now at Columbia. At these Centers he's lead the efforts to fund and develop new MR research systems including the first 2T, 4T, 7T, 9.4T and 10.5T human bore systems and with them has pioneered many new applications for brain and body biomedical research. His achievements are recorded in 120 articles, a number of books and chapters, and 51 patents either licensed or now in public domain. Vaughan has advised dozens of students and post docs, many of whom are major contributors to the field today. He is a leading pioneer in MR and its utility for science and medicine. Thomas Vaughan is a Fellow in the IEEE and ISMRM societies, on the editorial board of NMR in Biomedicine, active in the NIH and journal peer review, CTO of two small biotech businesses, and on advisory boards of additional international companies, societies, schools and foundations.

B. Positions and Honors

Positions and Employment

1979 - 1982 NASA, Kennedy Space Center: Digital Electronics Design Division, Design Engineer
1982 - 1984 Texas Instruments: Advanced Systems Division, Electrical Design Engineer
1984 - 1989 Univ. of Texas Southwestern Medical Center: Radiology, Radio Frequency Research Engineer
1989 - 1992 Philips Research Laboratory, Hamburg Germany: Technical Systems, Radio Frequency Scientist
1989 - 1993 Univ. of Alabama at Birmingham: Div. of Cardiovascular Diseases, Chief Biomedical Engineer

1994 - 1995 Univ. of Alabama at Birmingham: Biomedical Engineering, Assistant Professor
1995 - 1999 Massachusetts General Hospital NMR Center: Radiology, Director of Engineering
1995 - 2001 Massachusetts General Hospital: Radiology, Assistant in Physics
1995 - 2001 Harvard University: Radiology, Psychiatry, Assistant Professor
1998 - 2001 New England Regional Primate Research Center : School of Medicine, Resident Scientist
1999 - 2004 Univ.Minnesota Radiology,Electrical Engineering,Biomedical Engineering, Assoc. Professor
2005 - 2016 University of Minnesota: Radiology, Biomedical Engineering, Electrical Engineering, Professor
2014 - 2016 7T task force, Brigham and Women's Hospital / Harvard Medical School
2016 - University of Minnesota Radiology, Adjunct Professor
2016 - Columbia University School of Engineering & Applied Sciences: Biomedical Engineering, Professor
2016 - Columbia University College of Physicians & Surgeons, Radiology, Professor
2016 - Columbia University Zuckerman Mind, Brain, Behavior Institute, Member, MR Platform Director
2018 - Columbia University School of Engineering & Applied Sciences, Physics and Applied Math, Professor
2018 - Columbia University, Director of Columbia MR Research Center

Honors
Phi Beta Kappa, National Scholastic Honorary
Pi Mu Epsilon, National Mathematics Honorary: Member
Eta Kappa Nu, National Electrical Engineering Honorary: Member
Tau Beta Pi, National Engineering Honorary: Member

1993	UAB Biomedical Engineering Dept.: Outstanding Graduate Student of the Year
1993	UAB School of Engineering: Dean's Award for Outstanding Student of the Year
2005 - 2007	ISMRM Board of Trustees
2009	ISMRM Fellow
2014 -	Board of Advisors, Tra Vinh University, Viet Nam
2014	IEEE Fellow
2014	ISMRM Gold Medal nominee
2015	University of Minnesota Quist-Henline Chair of Biomedical Research

Other Experience and Professional Memberships

1981 -	Institute for Electrical and Electronics Engineers (IEEE); Engineering in Medicine and Biology & Medical Imaging
1989 - 1997	Society of Magnetic Resonance in Medicine (SMRM)
1997 - present	International Society for Magnetic Resonance in Medicine Committees served include: Board of Trustees 2005-2007, Chair Engineering Study Group 1997-1999, Chair Safety Study Group 2009-2010, Workshop Committee 1997-1999, Scientific Planning Committee 1998-2001, Educational Committee, YIA sub Committee, Governance Committee, Development Committee, Archives Committee, Safety Committee, Abstract Reviewer, Moderator, Faculty, Fellow, etc.
1987 -	Biomedical Engineering Society
1995 -	Journal for Physics in Medicine and Biology-Referee
1996 -	IEEE Transactions in Biomedical Engineering - Referee
1995 -	Journal of Measurement Science and Technology- -Referee
1996 -	IEEE Transactions in Medical Imaging - Referee
1997 -	Magnetic Resonance in Medicine - Referee
1997	Journal of Magnetic Resonance - Referee
1998 -	NMR in Biomedicine – Editorial Board
1994 -	National Institutes of Health, Reviewer for R-43, R-41, R-21, R-01, P-41 grant applications.
1997 -	National Science Foundation, DBI – Reviewer
2009 -	University of Minnesota, Faculty Senate Research Committee

C. Contributions to Science
My contributions to the MR field lie primarily in the engineering and physics research and development to advance this biomedical instrument and its applications. One of the main thrusts toward the advancement of MR technology and applications has been toward increasing the field strength of the MR magnet to gain signal-to-noise, speed, spatial resolution, spectral resolution, and some contrast mechanisms by which MR images and

other measurements are made. In the evolution of increasing MR field strength, from 0.35T to 10.5T for human imaging, I have been lead engineer or a PI at every step. While many system components such as magnets and computers were specified, purchased and integrated into a system, the radio-frequency / analog (RF) spectrometer and modes of application always had to be custom- built, often requiring invention and discovery. By this process of developing new and more powerful MR systems to facilitate new biomedical discovery, my teams and I have pioneered the development of high field MRI, MRS and fMRI technology, methods, and safety. Over 120 journal articles, 50 patents, and hundreds of reviewed abstracts and meeting proceedings document this history. My work, much of it licensed and used in the industry, has helped to shape many of the understandings, technologies and practices of MRI today. A select dozen of many more contributions were chosen to support my account following.

1.) High field systems

First 1.8T system. I served as Lead RF Engineer on the design, development, construction and application of a 1.8T, whole body NMR system at UT Health Science Center Dallas (now UT Southwestern), beginning in 1984. This system, aimed at multi-nuclear metabolic imaging was built in house concurrent to General Electric's effort to produce the first 1.5T commercial system. Development of this system and its application to human NMR studies, especially cardiac metabolism were the objective of UT Southwestern's first MRI based NIH Center grant. This 1.8T system was significant in achieving for the first time human images and spectra at a field strength more than five times of the high clinical field strength of 0.35 T at the time. Successful images were acquired at the Larmor frequency of 74 MHz, more than 7 times the frequency limit of 10 MHz predicted in the literature. Part of the success was attributed to my development of the first patented parallel transceiver arrays, RF shimming, and 3D physiological loading phantoms.

First 4T system in US. Beginning in 1989 as UAB's Chief Biomedical Engineer at Philips Research Labs in Hamburg, Germany, I designed, built, and applied the first 4T (4.1T) MRI / MRS whole body system delivered to the US, at the University of Alabama, Birmingham in 1990. This system was designed and built from component level up (capacitors, inductors, resistors, ICs, boards and connectors). A number of new technologies were invented and developed to make this system and this field strength successful. One significant innovation was the high power, active transmit receive switch for high peak power, pulsed MRI. Special, nonmagnetic, high voltage, low capacitance PIN diodes had to be developed to make this switch possible. These switches are now standard in the industry. Another significant innovation was the first distributed FET, solid-state, high power pulsed, radiofrequency power amplifier. Three of these class AB linear, 15kW amplifiers were developed, designed and built for this early 4T system to provide enough RF power to make robust whole body imaging at 4T possible for the first time. One more key series of inventions were during this project were multichannel transverse electromagnetic (TEM) coil design approaches for more efficient transmit, receive and RF field shimming options to correct for RF field inhomogeneities, loses and consequential heating at these here-to-fore unprecedented Larmor frequencies (170 MHz). These multi-tune TEM coils also proved most efficient for multi-nuclear NMR. These are covered in more detail below. Many of these (GE, Samsung, Siemens, etc.)

First two 7T MRI/MRS systems. In 1995, I was recruited as an Assistant Professor at Harvard, an Assistant Physicist at the MGH and as Director of Engineering at the MGH NMR Center (now Martinos) to establish a high field, whole body program at the Massachusetts General Hospital NMR Center. During this time, my team and I sited a 3T system and staffed and funded a 7T human system and a 9.4T preclinical system through competitive NIH and DOD grants. We also won seed money for a 9.4T human head imaging system for Harvard's now closed New England Primate Research Center. I took the grant for this magnet with me when I accepted a tenured professorship at the University of Minnesota's Center for Magnetic Resonance Research (CMRR) as PI of the Engineering Core where we achieved the first 7T human imaging results at the CMRR in 1999. Many firsts were achieved in human head and body imaging on the Minnesota 7T system. This followed an 8T head-only effort at Ohio State. I have helped to secure funding for and/or have advised/consulted on several addition 7T MRI systems including a second system at Minnesota, and those at Auburn AL, Iowa, Oxford, Brigham and Women's Hospital and now for two being ordered for Columbia.

First 9.4T MRI/MRS. My seed grant and plans for a 9.4T MR system originally intended for Harvard were instead used to leverage Keck Foundation funding (Ugurbil, PI) to fund the development and implementation of the first 9.4T system to achieve human head images, in 2004. To meet the technical and methodological challenges of imaging the human brain at the unprecedented Larmor frequency of 400 MHz, programmable, algorithm driven B1 shimming (phase and magnitude) was first developed for and implemented on this first 9.4T system. "Steered" RF spatial localization and scanning was first demonstrated on this system. Highest signal-to-noise (SNR) to date facilitated 10 micron in-plane resolution in images of the cat brain. 9.4T images revealed the highest spatial, temporal, and spectral resolutions ever achieved from large lab animals and humans In-vivo. I am currently searching for a home for this system at Columbia.

First 10.5T MRI/MRS. I served as a principal on the team to site and bring to operation the world's first and only 10.5T whole-body human system (Kamil Ugurbil, PI) at the CMRR where my engineering group has played a major role in the specification, installation, implementation, RF design and safety compliance of the first 10.5T, whole body MRI / MRS system now being installed in Minnesota. First phantom and large animal (porcine) results have already proven the system operational. IRB approval is currently being sought for the first human studies. To gain IRB approval, and investigational device exemption (IDE) must first be gained from the FDA. Toward this goal, my group has conducted critical safety and efficacy studies through both numerical simulations and experimental validations using human-adult sized, live porcine models.

2.) Transmit and receive technologies applied to MR systems.

Parallel (multi-channel) transmit and receive technologies. Borrowing from my early career with NASA and Texas Instruments using phased array radar, I brought RF transmit and receive arrays to the early MRI field, beginning in 1986 to cover the larger clinical sized volumes with arrays of multiple, smaller and more efficient loops required by the then unprecedentedly high frequency of 77 MHz. These loops were both actively decoupled with diodes and passively decoupled by overlapping loops and geometric arrangement. Later, arrays of loop and linear transmission line (TEM) elements were similarly employed. Not only coils but a whole parallel transmit and receive system and methods were developed to manipulate multiple, independent transmit and receive signal channels in five degrees of freedom: phase, magnitude, frequency, space, and time.

RF field "shimming". These arrays of loops, and later transmission line (TEM) elements were also employed though independent placement, drive and control to profile, adjust, or "shim" the RF excite and receive fields over an anatomic ROI. By controlling the phase, magnitude, frequency, timing and spatial configuration of RF transmit and/or receive signals on multiple, independent coil elements, a wide variety of new RF based MRI acquisition methods and protocols are possible. RF (B1 + E field) shimming has already proven especially useful in compensating RF artifacts created by short-wave interference patterns at increasing high, Larmor frequencies.

RF modeling. Since the late 1980s, I recognized and employed the power of numerical radiofrequency modeling in MRI, first using the finite element method, (FEM). I demonstrated the first true, full-wave, 3D modeling of loaded RF coils to the SMRM in 1993. Since then, I and the rest of my field have relied on this tool for RF coil design, RF shimming, RF safety predictions, and RF pulse protocol development.

RF safety. Understanding the propagation and loss of RF fields in anatomy is critical to coil and pulse sequence design, and to RF safety. The development, application, and validation of numerical and experimental tools for these purposes have been significant areas of contribution for me and my team. Development and use of new numerical simulation methods, more accurate bioheat transfer models, and reliable In-vivo animal models have been critical to meeting FDA-IDE, 510K, CE, IRB and IACUC requirements for human safety and ethical lab animal care with our many new MRI systems, technologies and techniques. In my work, I have emphasized the need to replace SAR with temperature as the primary safety metric for our field.

Physiological phantoms. Considering the need to account for RF coil loading and field performance in human anatomy sized volumes at relatively high frequencies, I developed the first physiology mimicking phantoms in the 1980s to replace then used silicone oil filled "bricks" and slices. My phantom patents claimed and included physiological conductivity and permittivity for accurate coil loading and image calibration, resolution grids, slice thickness ramps, field linearity and homogeneity grids, inserts for media of different relaxation constants accompanying measurement methods and many other claims considered standard for today's phantoms and practices. Development of many new head and body phantoms to explore and explain RF propagation and loss in tissue mimicking media at ultra-high fields have continued since.

RF coils. My work is particularly well known for development of RF coils and related interface and control systems, especially those referred to as transverse electromagnetic or "TEM" circuits. Per practice in the electronics industry, when circuits exceed 0.1 wavelengths they are made more efficient, less radiating, and with better current control by building them by transmission line principles and with Maxwell (time-harmonic) field calculations as opposed to lumped element designs and Biot Savart (static) field predictions. The same rules apply to RF coils which become significantly longer than 0.1 wavelengths for head and body sized circuits at Larmor frequencies including and above 64 MHz. Any circuit that can propagate a TEM wave is a transmission line by definition, hence the choice of the term. TEM coils include the executions using coaxial line elements, microstrip and stripline elements, coaxial cavities and waveguides. My teams and I have have designed and built hundreds of these coils of every variety and for every application for use in laboratories and clinics around the world. Many more are in use today in research and clinical systems.

Dielectric interfaces. The use of dielectric "pads" is an increasingly popular means of shaping or focusing the RF field to correct for field non-uniformities at higher frequencies, and to lessen the coil-air-patient impedance boundary. Some of these approaches were first explored and patented by me in the 1990s.

On-coil power amplifiers. Conventional RF power amplifier technology imposes a limit on the number of transmit channels that can be interfaced on a coil, given the need to attach bulky, high power cables to every element. Additionally these long, transmit cables as well as combining RF signals from multiple power transistors, 'FETs' in the amplifier reduce transmit signal efficiency by 2/3 or more, adding significantly to the loss and cost of the transmit system. By distributing the power FETs without combiners or cables over the surface for the coil array itself, high-count multi-channel coil arrays can become realizable, efficient and affordable.

Automatic tuning and matching. Currently in research applications, multiple coil elements in multi-channel transmit arrays must be independently, manually tuned and matched for best coil performance. This arduous, time consuming process could preclude the full clinical utility of multi-channel transmit coils. Two automatic, feedback driven, coil array element tuning and matching methods have been developed: electomechanical via piezomotors and electronic via PIN diode switching of capacitance matrices. Both methods have proven to be successful.

3.) Accessible MR.

According to the World Health Organization, 2/3 of the world does not have access to MR, even though MR is the preferred and safest means of high-resolution imaging especially for children, as opposed to X-ray and CT using ionizing radiation. Beginning with an Obama BRAIN Initiative grant titled, "Imaging human populations in real-world environments", my co-PI Michael Garwood and I demonstrated the feasibility of three key technologies in our BRAIN grant MH 105 998 to make MRI more accessible to the world. Specifically we demonstrated a persistent, liquid N2 cooled double pancake magnet coil, a simultaneous transmit and receive RF coil and front end, and the ability to acquire and reconstruct images from a non-uniform magnet field. We incorporated these ideas into a new BRAIN grant,U01EB025153 to be used at the Zuckerman Institute for motor control studies.

Complete List of Published Work in My Bibliography:
https://www.ncbi.nlm.nih.gov/myncbi/john.vaughan.1/bibliography/public/

D. Research Support

Ongoing Research Support

NIH 1U01 EB025153-01 M Garwood, PI; JT Vaughan PI of Columbia Subcontract 9/30/2017-6/30/2022
Institution: University of Minnesota with subcontract to Columbia U.
"Imaging Human Brain Function with Minimal Mobility Restrictions"
Aims: To design, build, and apply an MRI system for imaging brain function in subject with arms & eyes free to interact with environment. Instrument will be delivered and used in Zuckerman Institute for neuroscience studies.
Role: Columbia subcontract PI

RISE 2018 V. Ferrera, N. Kriegeskorte, T. Vaughan 7/1/2018-6/30/2020
Columbia University RISE Award
New Methods for Tracing Parallel Visual Pathways in the Non-human Primate Brain
The goal of this project is to map visual information processing across the entire brain using a unique combination of functional neuroimaging and targeted manipulation of neural activity using chemical and optogenetic approaches.
Role: Co-PI

Completed Research Support

NIH 5R24 MH105998-03 JT Vaughan, M Garwood MPIs 9/26/2014-5/31/2017
Institution: University of Minnesota with subcontract to Columbia U.
Imaging brain function in real world environments and populations with portable MRI
Aims: To test concept feasibility of a new, nitrogen temperature magnet, new imaging physics and a new RF/analog spectrometer to make MRI possible anywhere in the world.