The Marconi Society

Press Release

Stanford Professor A.J. Paulraj Wins the 2014 Marconi Prize

Honored for his pioneering contributions to developing the theory and applications of MIMO antennas

Palo Alto, CA, January 21, 2014—Professor (Emeritus) Arogyaswami Joseph Paulraj, Stanford University, has been awarded the prestigious 2014 Marconi Society Prize. His idea for using multiple antennas at both the transmitting and receiving stations - which is at the heart of the current high speed WiFi and 4G mobile systems – has revolutionized high speed wireless delivery of multimedia services for billions of people.

"Paul (as he is commonly known) has made profound contributions to wireless technology, and the resulting benefit to mankind is indisputable. Every wifi router and 4G phone today uses MIMO technology pioneered by him," says Professor Sir David Payne, Chairman of the Marconi Society and Director of the Optoelectronics Research Centre at the University of Southampton. "MIMO will soon be pervasive in all wireless devices. Moreover, Paulraj's work has provided fertile ground for thousands of researchers to explore and advance MIMO's potential to enhance wireless spectrum efficiency."

The Marconi Society, celebrating its 50th year in 2014, was founded by Gioia Marconi Braga. Each year it recognizes one or more scientists who – like her father, radio inventor Guglielmo Marconi – pursue advances in communications and information technology for the social, economic and cultural development of all humanity. Winners, who receive a $100,000 prize, have included scientists whose mathematical theories and inventions have shaped the Internet and broadband access, public key encryption, Web search, wired and wireless transmission, multimedia publishing, optical fiber and satellite communications.

Paul's story is a remarkable one. A native of India, a brilliant and always a top ranking student, he finished high school at 15 and having no career guidance, joined the Indian Navy. He opted for the electrical engineering branch, where his training focused on practical skills for maintaining weapons systems. But Paul wanted more and taught himself subjects like control theory, information theory and signal processing. He so impressed his superiors that in 1969 the Navy sent him to the Indian Institute of Technology (Delhi), one of India's top schools, for a MS program. His performance there quickly attracted the attention of Prof. P.V. Indiresan, an influential EE professor who urged the Navy to allow Paul to enroll in the Ph.D. program. Indiresan's persistence eventually overcame opposition both from the IIT Senate and from the

Navy, allowing Paul to switch to the doctoral program with just two years to wind up his research.

That opportunity changed Paul's life. In 1970, Stanford Prof. Thomas Kailath, a brilliant and influential systems theorist, visited IIT Delhi to lecture on non-linear estimation. Inspired by Kailath's lectures, Paul went on to make fundamental advances in non-linear estimation of signals using advanced tools from Ito calculus and stochastic diffusion theory. The Navy also got a big payoff. In 1971, a brief war with Pakistan exposed the shortcomings of the Navy's (British origin) sonars leading to the loss of a Naval ship. Paul led a successful project to redesign the sonar adding many new signal processing concepts. Three years later the new technology was widely deployed in the fleet.

After a brief fellowship at Loughborough University U.K., the Navy assigned him to lead a much more ambitious project to design an advanced technology sonar not available to India because of military export restrictions. Overcoming difficult circumstances, his team developed a world-class sonar system (APSOH) that was inducted into fleet service in 1983, a stunning achievement in military electronics for India. APSOH to this day ranks among the best sonars in the world. Retired Admiral R. H. Tahiliani, former Chief of the Naval Staff, recalling APSOH says, "The Navy is enormously proud of Paul's many achievements and will remain always indebted for his landmark development of the APSOH sonar."

Following APSOH work, Paul was given a two-year sabbatical leave to explore new areas, and his scientific supervisor suggested he should try to work at Stanford University. Paul wrote to Prof. Tom Kailath, who despite initial skepticism, finally agreed to allow Paul to join his research group. Paul recalls "Coming to Stanford was one of the most fortunate breaks in my life, I am very grateful for the opportunity. Tom has an uncanny nose for choosing researchers and the people he attracted to his group helped make Stanford a top engineering school."

At Stanford, Paul worked on a multiple signals Directions of Arrival (DOA) estimation problem that had a long history of improvements using a spectrum approach. Paul proposed a totally new method called ESPRIT (Estimation of Signal Parameters via Rotational Invariance Techniques).This led to a mini-revolution spawning more than 1000 papers and over 50 doctoral dissertations; its applications now go far beyond array signal processing to spectral estimation and to system identification. "ESPRIT came from a physical rather than a mathematical, insight," says Paul. "I was trying to generalize my Indian sonar work, and as usual was thinking about it in a visual manner; the mathematics followed easily".

Paul returned to India in 1986 and served as the founding director for three major labs in India - CAIR (Center for Artificial Intelligence and Robotics), CDAC (Center for Development of Advanced Computing) and CRL (Central Research Labs of Bharat Electronics). But by 1991, bureaucratic battles began to take their toll and with the consent of the Indian Navy, he returned to the U.S. and Stanford University. Admiral Tahiliani, commenting on Paul's difficulties adds, "His departure for Stanford University was a major loss for our country and the circumstances that led to his move may explain why we have so few Nobel Laureates from India."

At Stanford, while awaiting a faculty appointment, Paul worked on signal separation experiments for airborne reconnaissance. He noticed something surprising: in presence of scattering, co-channel wireless signals from closely spaced transmit sources were often separable by an adaptive receiver antenna array. A few days later, sitting in a barber shop, he had an idea for increasing throughput in wireless systems using multiple transmit and receive antennas (MIMO - Multiple Input, Multiple Output). Paul applied for an U.S, patent titled "Distributed Transmit – Directional Receive DTDR" (with his then supervisor Prof. Kailath as co-inventor) in Feb. 1992 and the patent was granted in Sep. 1994. Spatial Multiplexing, as this is now known, boosts spectral efficiency by creating "parallel spatial data streams" within the same frequency channel. Once again, it was visual thinking that sparked the idea. The rigorous, more mathematical details came from others, and indeed, many years later.

"When I stumbled upon the concept and potential of MIMO spatial multiplexing in 1991 I was troubled that such a simple idea might indeed not be original. Some years later, I discovered that Dr. Marconi had similar sentiments in 1895 when he first demonstrated wireless telegraphy," says Paul.

He need not have worried. The idea was indeed original. Moreover, his attempts to attract interest from the mobile technology companies and funding agencies were met with deep skepticism. His claim that a 1,000,000-QAM system could be built using MIMO when the state-of-art was then 4-QAM engendered disbelief. Now, 20 years later, the MIMO-based 802.11ac WiFi supports 16,000,000-QAM.

Following his appointment as Professor (Research) in 1993, Paul built a large research group around MIMO at Stanford that has since graduated over 50 doctoral and post-doctoral students, many of whom have gone on to become important leaders in their own right.

Undaunted by the skepticism about MIMO's practical feasibility, he took leave from Stanford in 1998 to found Iospan Wireless Inc. (initially known as Gigabit Wireless) and built a MIMO based commercial system. Venture firms finally paid attention after he demonstrated a 3x3 MIMO radio he built with his personal funds. While CDMA access technology was still the mainstay of the wireless industry, Paul pushed for OFDMA as the best access technology for incorporating MIMO. Iospan developed a MIMO-OFDMA based fixed wireless system to offer 4096-QAM with 2 spatial streams. By 2001, Iospan had firmly established that MIMO offers good value in typical cellular applications. Intel Corp. acquired Iospan's technology in 2003, and Paul worked with Intel to develop the WiMAX mobile standards.

In 2004, Paul co-founded Beceem Communications to develop semiconductor solutions and the company emerged as a world leader in WIMAX semiconductors with more than 65% market share. It was acquired by Broadcom Corp. In 2006 and the 3GPP standards group also adopted Iospan's MIMO-OFDMA as the core technology for the 4G mobile standards.

Stanford colleague and Marconi Fellow Prof. John Cioffi, the inventor of DSL technology, calls Paul's technical capability "almost unparalleled in the world. But what impresses me most is how Paul endured the tremendous, pressure, turmoil and stress of people saying his ideas weren't going to work, and persevered until he found success. Such people are pretty rare."

With characteristic modesty, Paul says, “MIMO technology is today embedded in 4G mobile and WiFi. It has taken the effort of thousands of engineers and researchers around the world, many of them truly eminent, to make this happen. My contribution, in comparison, is indeed small.” And with characteristic optimism, he says, “The potential of MIMO to multiply the capacity of wireless spectrum is seemingly limitless. Use of milli-metric band frequencies can soon enable much larger numbers of MIMO antennas and the corresponding boost in wireless capacity.”

Paul remains active, supervising Post-Doc students and serving as a Sr. Adviser to Broadcom Corp. He also maintains close ties to Indian IITs. Prof.Bhaskar Ramamurthi, Director IIT Madras, says, “Paul has enduring links with the entire IIT system. He has served on a variety of committees, mentored faculty members and even hosted some of them at his Stanford lab and his companies. He’s been a marvelous asset for the IIT system over the past four decades.”

Despite having received many awards and honors in the U.S. and India Paul says, “In telecom there are two top recognitions; the IEEE Alexander Graham Bell Medal which has a bias toward theoretical contributions, and the Marconi Prize, which honors contributions that convert breakthrough ideas into products benefiting billions of people. I am incredibly honored to have won both. The Marconi Prize emphasizes service to humanity. It is the highest recognition I can imagine.”

Paul was elected to the U.S. National Academy of Engineering (NAE) in 2006, and to several national academies around the world. Notably, his election to U.S, NAE was just a dozen years after starting a career in wireless research in the U.S. He has also received recognition in India for his work, including the Padma Bhushan, a major national award.

“Paulraj’s brilliance and perseverance have revolutionized wireless technology bringing a lasting benefit to mankind. He is a wonderful role model for researchers all over the world.” says Mr. Narayana Murthy, Executive Chairman Infosys and a noted pioneer of IT Services.

Although Paul and his wife Nirmala live on the Stanford campus, they are frequent visitors to India, where Paul emphasizes the need for India to build its own telecom technology industry. He hopes to find more ways to contribute personally to that goal.

“I have two grown and married children and we’re proud grandparents of four grandchildren,” says Paul. “I love spending time with my family, but I’m not ready to stop work yet. My biggest challenge is finding time for all the things I want to do.”

About the Marconi Society

The Marconi Society was established in 1974 through an endowment set up by Gioia Marconi Braga, daughter of Guglielmo Marconi, the Nobel laureate who invented radio (wireless telegraphy). It is best known for the Marconi Prize, awarded annually to an outstanding individuals whose scope of work and influence emulate the principle of “creativity in service to humanity” that inspired Marconi. Through symposia, conferences, forums and publications, the Marconi Society promotes awareness of major innovations in communication theory, technology and applications with particular attention to understanding how they change and benefit society.

Additional information about the Marconi Society and the Marconi Fellows can be found at www.marconisociety.org.

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