Career Path: From Researcher to Entrepreneur and Beyond

C.J. Reddy

Most industry careers in antenna engineering start with a researcher position and then develop into a managerial role. Initial research work could start with a master's/doctoral degree thesis, followed by a design/application engineering job in industry. Success in a research capacity is expected to lead to a managerial role. In this article, I examine my own career path, which took me from research, to entrepreneurial, to management positions. While most of my career was not planned, my experience could probably help those starting their work in industry to plan theirs.

EDITOR'S NOTE

In this issue of *IEEE Antennas and Propagation Magazine*, we are privileged to have an interesting contribution to our column from Dr. C.J. Reddy, who provides details of his professional journey from India, to Canada, and then to the United States. He discusses aspects of being a researcher and entrepreneur as well as now being with a multinational company. Dr. Reddy also talks about his philanthropic activity to establish the IEEE Antennas and Propagation Society (AP-S) C.J. Reddy Travel Grant for Graduate Students with the help of the IEEE Foundation and AP-S.

Rod Waterhouse

Anyone who would like to contribute to the "Industry Activities" column, or if there is someone you'd like to see an article on or from, please contact me at rwaterhouse@octanewireless.com. For the scope of this column, please refer to the December 2020 issue of *IEEE Antennas and Propagation Magazine*.

INTRODUCTION

A *career*, as defined by *Wikipedia* [1], is an individual's metaphorical "journey" through learning, work, and other aspects of life. Most of the antenna engineers in industry start their careers conducting research in one form or another and then progress based on opportunities presented to them along the way. Success or failure can then depend on how well these opportunities, no matter small or big, are taken advantage of. In this article, I chronicle one career that is most familiar to me—that is, my own—so there may be a few lessons learned that are useful to those starting their own careers in industry.

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My research career began when I was a doctoral student in India and continued with postdoctoral fellowships in Canada and the United States. Then, I ended up leading two start-up companies, one of which was acquired by a larger multinational company, where I am currently leading business development activities in the Americas.

RESEARCH CAREER

As mentioned, I started my research career as a doctoral student at the Indian Institute of Technology (IIT), Kharagpur, India, analyzing striplines and microstriplines [2] conformal to cylindrical surfaces (Figure 1) in the mid-1980s. I was told that a Ph.D. topic should be 1) a new problem with a new solution, 2) an old problem with a new solution, or 3) a new problem with an old solution—but, of course, it cannot be an old problem with an old solution. Another good piece of advice from my Ph.D. supervisor was to start submitting to IEEE publications as soon as possible so that the research work was peer reviewed and published, making it easier to defend my thesis when the time came. With this guidance, I completed my Ph.D. degree successfully in two years' time with three articles in *IEEE Transactions on Microwave Theory and Techniques* and two in non-IEEE journals.

Once my Ph.D. work was completed, I joined a "start-up" research organization, the Society for Applied Microwave Electronics and Engineering Research (SAMEER) in Mumbai, India, to work on radar system design and slotted waveguide arrays for high-resolution radar. This provided me with insights into real systems and the design process of a product from the ground up.

Due to my interest in advancing my research career, I was also applying for postdoctoral positions in the United States and Canada. I was fortunate to be awarded a Visiting Fellowship at the National Sciences and Engineering Research Council of Canada (NSERC) in 1991 to work at a Canadian government research organization, the Communications Research Center (CRC) in Ottawa, Canada.

I was given the assignment of investigating nonradiating dielectric (NRD) waveguides [3]. Since the emergence of new communication technologies in the 1980s, there was an increasing need for high-performance millimeter-wave systems. The NRD waveguide was proposed as a promising transmission medium at millimeter-wave frequencies because of its low-loss nature and ability to suppress radiation at curved sections and discontinuities. In a way, one can think of the NRD waveguide as a predecessor to the substrate-integrated waveguide [4].

My work included starting research on NRD waveguides from the ground up, designing the transition from a rectangular to an NRD waveguide, analyzing the narrow radiating slot excited by NRD [5], and, finally, using the slot to excite a microstrip patch antenna [6]. What made this work interesting for me was that I could successfully do the design, analysis, fabrication, and measurements (Figure 2) during my tenure as an NSERC fellow at the CRC. It is interesting to note that there were

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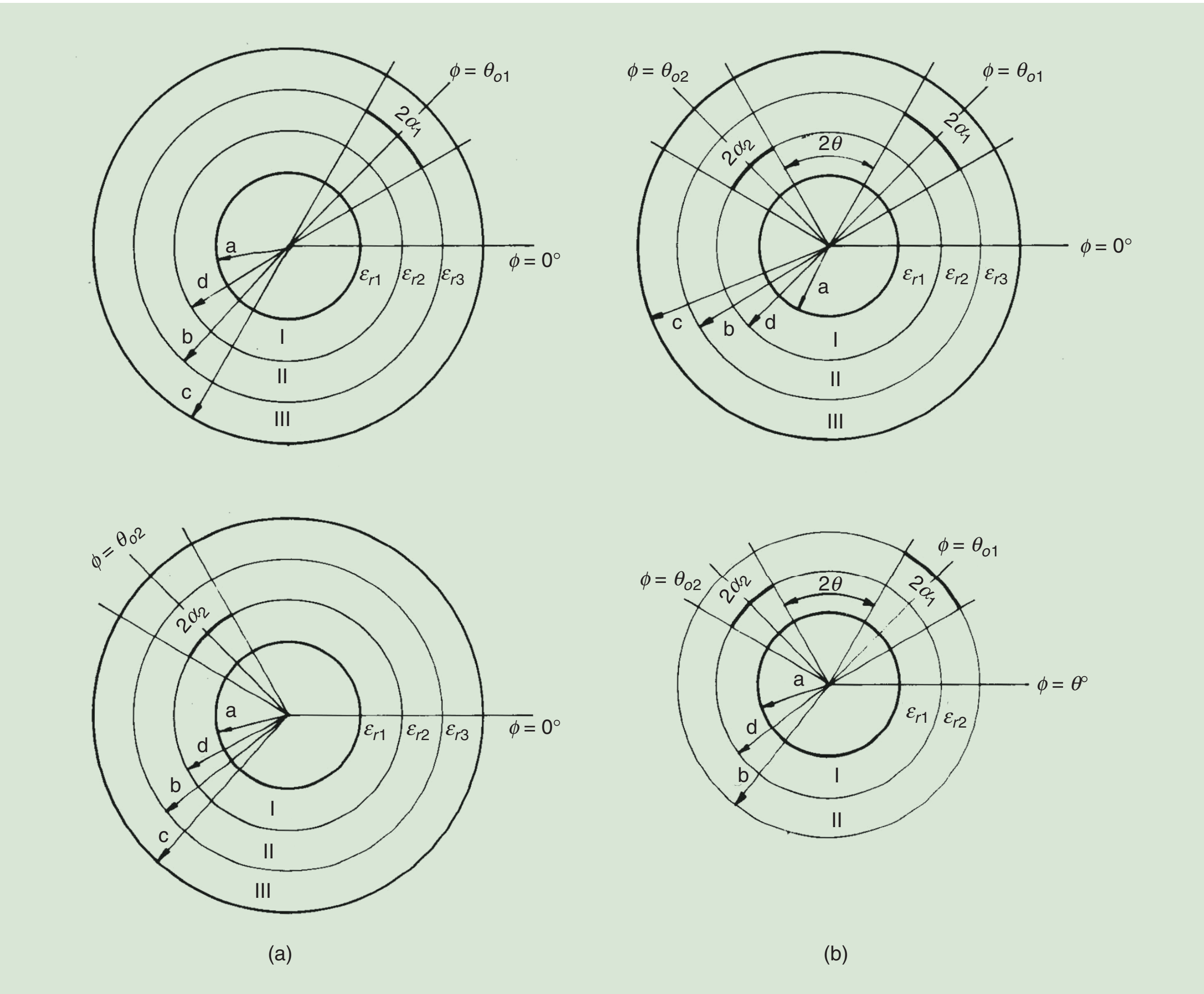

FIGURE 1. (a) The cylindrical striplines between two ground planes filled with a layered dielectric. (b) The coupled cylindrical striplines and microstriplines at the interfaces of a layered dielectric. (Source: [2].)

no commercial electromagnetic (EM) simulation tools at that time, so the analysis was done by using a modal expansion method combined with reciprocity and the Poynting theorem to develop an equivalent circuit model.

During this time (1993), I was again fortunate to be selected for the U.S. National Research Council's (NRC's) Resident Research Associateship program to work at the NASA Langley Research Center in Hampton, Virginia. This was a turning point in my career, as it opened the doors for my journey into the exciting field of computational EM (CEM). At NASA, I was given the assignment of developing a hybrid finite-element (FEM) and method-of-moments (MoM) solver for cavity-backed antennas. I had not worked on numerical methods before, so I needed to start from scratch to learn and implement FEM and MoM solvers.

Also, this was the time when FEM had overcome the problem of nonphysical spurious solutions due to nodal-based methods and found new life with the application of "vector basis" or "vector elements," which assign the degrees of freedom to the edges rather than nodes of the element. My learning of FEM started with solving a scalar 2D Helmholtz equation for computing cutoff frequencies of waveguides of arbitrary cross sections and, then, a 3D vector wave equation for computing the eigenvalues of arbitrarily shaped cavities. My learning process was documented in a NASA technical paper [7] that has become my second-most-cited publication and is used at many universities to teach FEM to students. With the progress made with FEM, I could successfully complete my assignment of developing a hybrid FEM/MoM method for cavity-backed antennas [8] within the two-year tenure of my NRC associateship.

My research career continued at the NASA Langley Research Center while I worked as a research professor at Hampton University from 1995 to

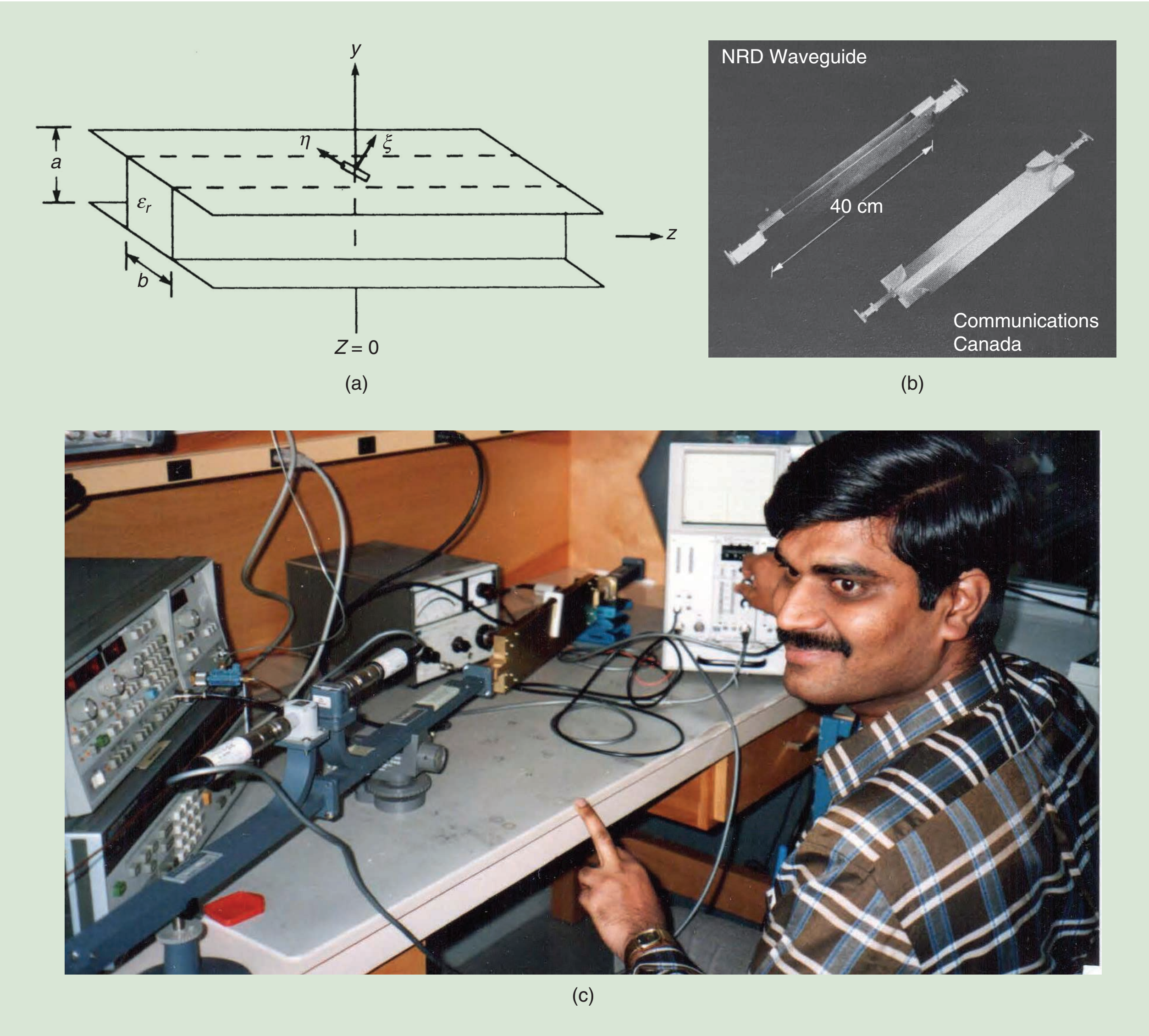

FIGURE 2. (a) The NRD waveguide with a narrow slot [5], (b) a fabricated NRD [5], and (c) the measurement of the fabricated NRD waveguide at the CRC.

2000. During this time, I could extend my research to implement model-based parameter estimation (also sometimes referred to as *asymptotic waveform evaluation*) for fast-frequency sweep calculations [9], [10]. My association with Hampton University also provided me with an opportunity to teach undergraduate courses in electrical engineering, starting with Engineering 101 to freshmen, Network Theory to juniors, and Electromagnetics to seniors.

ENTREPRENEURSHIP

A popular saying is that "necessity is the mother of invention." In my case, this was true in becoming an entrepreneur. After spending more than 15 years in research, I had an opportunity to start a company, Applied EM, Inc., to develop innovative antenna solutions. The idea was to collaborate with the best-in-the-business academic minds and work on the U.S. government's Small Business Innovative Research (SBIR) program to develop new antenna technologies. As a novice entrepreneur, I joined a local nonprofit technology incubator to train myself in contract negotiations, accounting, and other business-related skills that are needed to run a small company.

With successful collaborations with universities, Applied EM participated in more than 30 phase 1 and 20 phase 2 SBIR projects. A few unique technologies developed at Applied EM include the following:

- *Compact wideband direction-finding (DF) antenna* [11]: Applying the broadband spiral antenna technology, a compact (with a height of 5.5 in and a diameter of 15.5 in) wideband (70–3,000 MHz) DF antenna (Figure 3) for the U.S. Navy was developed, and the performance was successfully verified with measurements.
- *"Paint-on" antenna technology* [12]: Unlike "direct-write" technologies, "paint-on" antennas can be painted on any surface (conducting, nonconducting, small, large, planar, or curved), making this suitable for the robotic painting of large antenna arrays (Figure 4).
- *Uniform theory of diffraction (UTD) for faceted geometries* [13], [14]: Of all the CEM tools available today, only UTD does not require frequency-dependent discretization and has a computational cost independent of the frequency. However, available UTD codes require that the relevant geometry be approximated with simple canonical shapes. Thus, it requires an expert user who can make the approximate model represent the original model accurately in an EM sense. Applied EM developed a new UTD code, uCAST (Figure 5), which employs smooth facets directly from actual CAD geometries, which can remove these limitations. Developed under the U.S. Navy SBIR projects, uCAST simulations avoid costly retrofits in antenna placements and the need for many expensive antenna measurements to determine the optimal placements of antennas on complex structures. The integration of this technology into commercial EM simulation tools is in progress and will be available in the near future.

At the peak of its operations, Applied EM had around 14 employees, with most of them having advanced degrees in EM. Applied EM closed its doors in December 2017, but the innovative antenna technology and

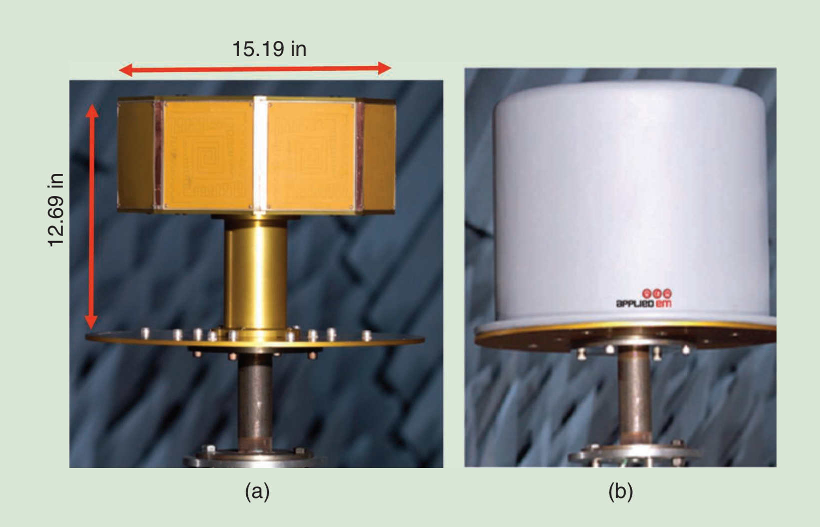

FIGURE 3. A compact, broadband, DF antenna developed by Applied EM for 70–3,000 MHz. (a) Without radome cover. (b) With radome cover.

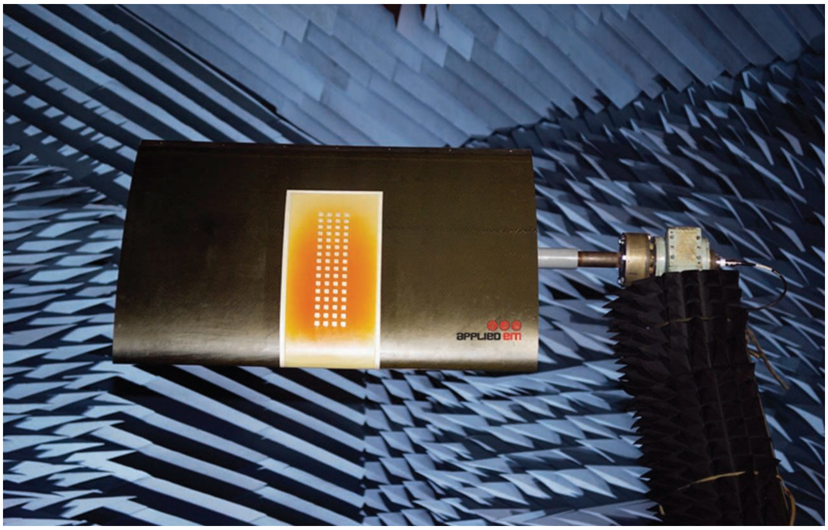

FIGURE 4. A "paint-on" microstrip patch antenna array on a composite aircraft wing.

simulation tools developed under various SBIR projects will continue to have a lasting impact as antennas become ubiquitous.

In the early 2000s, when Applied EM started growing, I was also approached by EM Software and Systems-SA Pty. Ltd. (EMSS) from South Africa to distribute the commercial EM simulation tool, Feko, in North America. Feko was then just getting a foothold in the market. While I had never been involved in sales and marketing efforts, I agreed, mainly due to my background in CEM and passion for popularizing simulations for antenna designs in industry as well as academia. So started EMSS (USA) Inc. (EMSS-USA) (Figure 6) as a separate entity from Applied EM. Initially, it was mostly a one-person operation, with me taking care of technical support, training, sales, and marketing in North America. Feko being the first commercial simulation tool with hybrid full-wave and asymptotic techniques, it soon became a standard in industry for antenna placement analysis on electrically large structures and has grown to be one of the leading EM simulation tools.

Running EMSS-USA gave me an opportunity to work with antenna engineers across many industry verticals, broadening my view of the growing applications of antennas and EM, not only in the defense and aerospace industries but also in consumer and medical electronics. As part of marketing efforts, I also had the opportunity to attend various conferences. The IEEE Antennas and Propagation Society's (AP-S's) annual flagship conference provided great opportunities to not only market the software but also present papers on a wide range of applications, benefitting me both personally and professionally.

EMSS-USA was acquired by Altair in 2014, along with all other EMSS companies worldwide, adding Feko to Altair's growing portfolio of engineering simulation tools [15]. Running two small companies, one (Applied EM) that developed innovative antenna technologies and another (EMSS-USA) involved with marketing and selling commercial EM simulation tools, provided me with different but complementary career accomplishments. It gave me the great opportunity to mentor young engineers who were employed at Applied EM and EMSS-USA.

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AND BEYOND

With the acquisition of EMSS-USA and Feko by Altair, I transitioned to Altair as vice president of business development–EM for the Americas. This started a new phase in my career: I became part of a large multinational company with a wide range of engineering simulations, which opened more opportunities to apply multiphysics simulations to antennas and work on advanced topics, such as machine learning, 5G, advanced driver-assistance systems, and so on. With the evaluation of

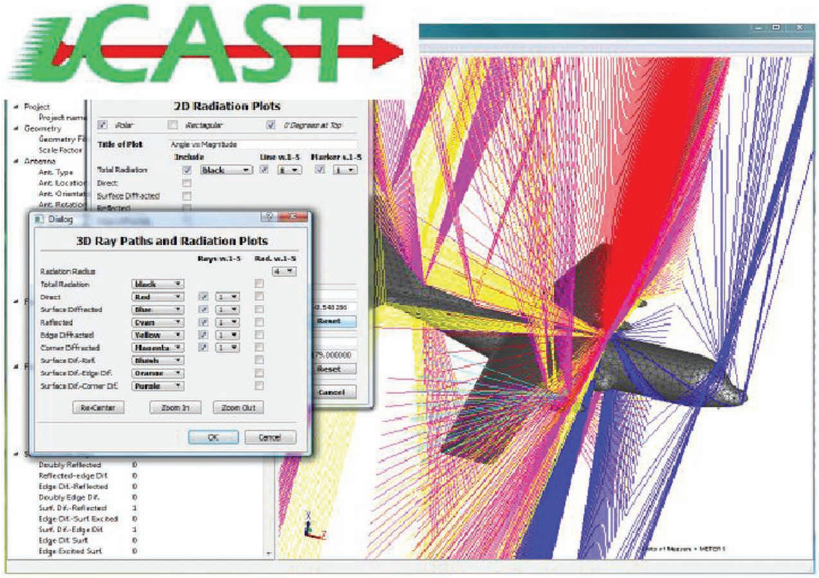

FIGURE 5. The UTD code suitable for faceted CAD geometries.

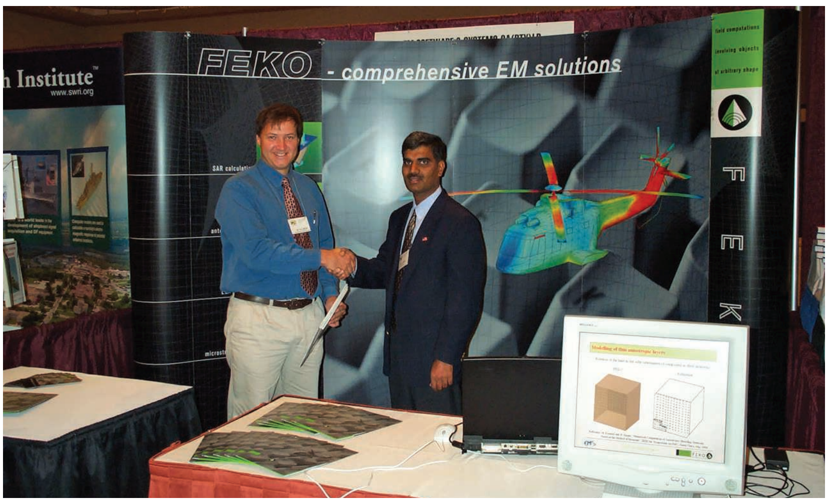

FIGURE 6. The start of EMSS-USA with (left) Dr. Frans Meyer of EMSS at the 2002 IEEE AP-S/URSI International Symposium, San Antonio, Texas.

new technologies, such as 6G, autonomous vehicles, the Internet of Things, and artificial intelligence, I can see an expanding and exciting horizon for antenna engineers to innovate and realize wireless products that can positively impact human society.

PHILANTHROPY

For most of us, including myself, philanthropy is not part of our career path. Recently, however, I realized that organizations like IEEE play a very important role in shaping our careers beyond our day-to-day job requirements. For nearly three decades, IEEE and AP-S played a significant role in my professional life, helping my career growth. Specifically, attending the annual IEEE AP-S/URSI International Symposium benefitted me both professionally and personally.

To provide the same opportunity for qualified young students, I established the IEEE AP-S C.J. Reddy Travel Grant for Graduate Students [16], [17] with the help of the IEEE Foundation and AP-S. The objective is twofold: 1) to provide qualified young students with the same opportunities I was afforded via attendance at AP-S conferences and 2) to offer an example for other IEEE Members as to how their philanthropy can make an impact. I hope my contribution to the Society can inspire others to give back so that we can encourage active research and innovation by future generations in the antenna field.

CONCLUSIONS

The main objective of this article is to examine my career path so that those starting their own can learn and benefit from it. As can be seen from this article, my career did not start with an end goal in mind but took me through various phases—each setting the stage for the next. One key element to note is that, when opportunities are presented, we can take advantage of them if we work hard and put our minds to it. Antenna engineering is a growing area of opportunities. I hope to see more students take up the challenge and become innovators of the next generation of antennas that will be part of future wireless products.

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AUTHOR INFORMATION

C.J. Reddy (cjreddy@altair.com) is the vice president of business development–electromagnetics for the Americas at Altair Engineering, Inc., Hampton, Virginia, 23666, USA. He is a Fellow of IEEE, the Applied Computational Electromagnetics Society (ACES), and the Antenna Measurement Techniques Association (AMTA).

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