Abstract: In this compressed retrospective, I shall try to convey a sense of the extraordinary burst of activity within microwave electrodynamics during the immediate post-World War II era (when the foundations were laid for what is taken for granted today), and how my own career was affected by it. The present generation of EM practitioners will have to decide whether, and to what extent, the analytic knowledge base assembled during the past half-century remains relevant for the tasks that lie ahead.

DEFINING THE QUEST

“We do not really deal with mathematical physics but with physical mathematics; not with the mathematical formulation of physical facts, but with the physical motivation of mathematical methods. The oft-mentioned “prestabilized harmony” between what is mathematically interesting and what is physically important is met at each step and lends an esthetic -- I should say metaphysical -- attraction to our subject.”

Arnold Sommerfeld*

INTRODUCTION

To provide a proper perspective, it is useful to establish a brief educational chronology. I was born in 1924 to Jewish parents in Munich, Germany, and emigrated (to New York) in 1939 due to Nazi persecution before finishing my middle school education. I worked there at various odd jobs, going to night school when feasible, and spent 1943-46 (with one year overseas in the Philippine Islands) in the US Army. As a veteran, I became eligible to pursue a full-time government-supported college education, for which I selected the electrical engineering (EE) program at the Polytechnic Institute of Brooklyn (Brooklyn Poly; now Polytechnic University) because of my long-standing interest in electricity, graduating at the age of 24 in 1948. My post-graduate education at Poly began at that time (I remained there until 1994). Thus, I am one of the dinosaurs (hopefully not yet fossilized) who experienced as a graduate student the full thrust of the post-WWII scientific ambience. None of this would have occurred without the far-sighted veterans’ benefits program -- and a good deal of luck: Being at the right place (a high-profile institution with a high-expectation mentoring environment) at the right time (in a high profile-discipline with generous sponsored support). I would like to state emphatically that while a “personalized” presentation naturally uses the first person format, my career accomplishments were made possible only through (and are therefore shared by) collaborating students, post-docs, and professional colleagues.

THE RIGHT PLACE

Brooklyn Poly, through its Microwave Research Institute (MRI) affiliated with the EE Dept., turned out to be the right place for me. My recollection (which may be faulty in some details) is as follows. Under the leadership of Professor Ernst Weber, the EE Dept. Head, there had been assembled an organization and a research faculty of stature and international visibility, addressing diverse microwave-related specialties. Senior among the faculty was Professor NathanMarcuvitz who brought with him from the MIT Radiation Laboratory, and also through his affiliation with the Courant Institute of Mathematical Sciences at New York University (NYU), a broad knowledge base which he shared generously, through lectures and seminars, with students and faculty. It was he who offered me a research fellowship for the Master (MEE) and Doctor (DEE) degrees (awarded in 1949 and 1952, respectively), and who was my mentor, steering me in the direction of “quasi-optic” propagation and diffraction theory, high frequency (HF) asymptotics, and the spectral (characteristic Green’s function) theory of operators -- activities which were also current (through Profs. B. Friedman, K.O. Friedrichs, J.B. Keller, M. Kline, and W. Magnus) at NYU, and in which I participated.1 My dissertation, “Diffraction by Wedges and Cones” dealt with wave scattering by

* Extracted from the preface to “Partial Differential Equations in Physics” Sommerfeld[1].
1 Here is a partial sample of my reading list at that time: Marcuvitz[2], Friedman[3], Morse and Feshbach[4], Stratton[5], Whittaker and Watson[6], Jeffreys and Jeffreys[7], Watson[8], Bremmer[9].
surface-impedance-coated versions of these obstacles, emphasis being placed on HF asymptotic approximations for the edge or tip diffraction coefficients. Cone tip diffraction, even by perfectly conducting cones, was a hot topic within the radar cross section community on both sides of the (then) “Iron Curtain”. The visibility gained through conference presentations of my results allowed me to (fairly rapidly) establish my own research agenda. The guidance and contractual support provided by Marcuvitz (through programs sponsored by the Air Force Cambridge Research Laboratories (AFCRL)) during the transition process was much appreciated, as was my appointment to the MRI research faculty. In parallel with these activities, I benefited from discussions and collaborations with Professor Arthur A. Oliner, who was at that time concerned with the network theory and calibration of microwave measurements.

My First Eye-Opening “Esthetic” Encounter: The Watson Transformation. The Watson Transformation (Watson\[10\]) deals with the propagation of vertical-dipole-excited time-harmonic radio waves around a perfectly conducting model earth. It converts the azimuthally symmetric two-dimensional (2D) coordinate-separable scalar Green’s function (GF) $G(r,\theta)$ -- which was then conventionally expressed in terms of an (integer-$n$)-indexed series of $\theta$-domain spherical harmonic eigenfunctions and a (1D) $n$-indexed radial spectral GF -- into a an alternative series of nonconventional ($n \rightarrow \nu$)-indexed radial eigenfunctions and a (1D) $\nu$-indexed angular spectral GF. The latter yields remarkably better convergence properties, reducing to a few explicit contributing terms the (then intractable) typically $\sim 1000$ non-decreasing terms required in the spherical harmonics representation. Implementation (see Sommerfeld\[1, pp. 279-290\]) requires reformulation of the $\theta$-eigenfunction series as a contour integral in the complex $\nu$-plane that surrounds the $\theta$-eigenfunction- matched pole singularities (whose residues recover that series), and re-structuring the integrand so as to allow deformation of the contour (i.e., convergence at $|\nu| \rightarrow \infty$) around the spectral pole singularities which generate the radial eigenfunction series. I was fascinated by Watson’s ingenuity in finding a simple reformulation that yields the generating kernel from which either representation can be obtained. However, as I learned through my studies of the spectral theory of operators and “characteristic” GFs, that theory elegantly furnishes the desired kernel a priori, for all coordinate separable GFs, where Watson’s method of “ingenious devices” is much less direct. The characteristic-GF method has been one of the cornerstones in my analytic tool box ever since. I have often wondered whether the then crucial (see Bremmer\[9\]) Watson transformation would have been discovered, had computers been available to sum the 1000-term spherical harmonic series. This entire experience was the first that made me appreciate Sommerfeld’s “esthetic” as expressed in the citation up-front. I have tried to adhere to this concept throughout my subsequent attempts at constructing physics-based problem-matched wave-interaction strategies in complex environments, which become most satisfying when they have some attributes of “harmony” or “elegance”.

THE RIGHT TIME: THE GOLDEN YEARS

Because of the strategic importance of microwave generation, radiation, guiding and scattering in the post-WWII era, there was ample governmental financial support for disciplinary and interdisciplinary, university and industrial research and applications. Inter-institutional exchanges and collaborations were encouraged, as was the convening and attending of international scientific conferences, where the then latest results and controversial wave-dynamical issues (which are classroom material today) were vigorously debated. Within the EE student population, for many of the best, this was their area of choice. Though in uncomfortably crowded physical quarters, MRI was imbued with an air of “high expectations” that was not lost on the students there. Foreign nationals, especially from Japan and Germany, came to the US to catch up on progress that was disrupted by the war. There even were opportunities, at certain international conferences in the West and in the former Eastern bloc, for bilateral scientific exchange because of a common interest shared by both constituencies.

To sum up, there was at that time an air of ferment and excitement within the EM community which I have tried to convey because it is the farthest removed (in time) from the (21st century)-launched EM generation.

\[2\] My first assignment actually was diffraction by a dielectric wedge, a structurally simple but dynamically still rigorously-intractable problem, which I had to discard (after unsatisfactory attempts) for the simpler impedance boundary version.

\[3\] I had close connections with the Radiation Laboratory of the University of Michigan in Ann Arbor.
THE FOLLOWING YEARS
Brooklyn Poly (now Polytechnic University) remained the right place for me, having expanded its scope and international visibility by re-organizing under the umbrella of the Weber Research Institute (WRI). Within this relatively small private university setting with a correspondingly compact administration, I was able (with my research group) to fully pursue my programmatic research objectives. A highlight was my continued collaboration with Marcuvitz on our book (Felsen and Marcuvitz[11]), published in 1973, and translated shortly thereafter into Russian. There also were excursions into other disciplines like underwater acoustics, seismology, atmospheric propagation, guided optics, etc.; the EM methodological tool box (see Felsen[12,13]) is readily transferable, and it is reciprocally enhanced by interdisciplinary inputs4. On the educational side, there was mentoring on the pursuit of research and scholarship: a) Posing the question: What is the Question? (What are you looking for? What do you want to do? Why, and how, do you want to do it?); b) Self-analysis: It is important to know what you know, but it’s equally important to know what you don’t know; etc. The most rewarding experience (for the mentor and the mentored): When the mentored really knows. During the 1980’s (due to the interest shown in computers, and some economic downturns in the defense-driven EM job market), student interest in EM declined. For personal (family) reasons, I began to re-locate in Boston, splitting my time for a while between Poly, MIT’s Underwater Acoustics Dept., and Northeastern University’s EE Dept. I ended up at Boston University in 1994, but still maintain Poly-contacts.

EPILOGUE: MESSAGE FOR THE CURRENT GENERATION
The Holy Grail: Every scientific quest has its Holy Grail. It is something to aspire to, knowing that you never get there. But there are islands of satisfaction along the way, when you feel you have done something “nice”. That makes the journey worthwhile.

I have attempted to re-construct the career-launching conditions at what qualified as my right place (with a strongly analytic high-expectation mentoring environment) at my right time (addressing timely scientific issues), keeping my problem-matched physics-based Holy Grail in mind during the subsequent progression.

Question: Can the knowledge-base (methodological tool box) accumulated during my generation be helpful to your generation in your quest for the right mentoring career-launching place in your (computer-driven) time with its own “exciting” (Holy Grail) timely issues? It may be worth thinking about.

REFERENCES

* My favorite tool is probably the not-widely-used but elegant self-consistent hybrid ray-mode scheme (Felsen[13]).