Professor Willard Van Tuyl Rusch

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Professor Rusch left life on the morning of May 27, 1992, at the age of 58, while participating in a scuba-dive expedition off the coast of San Miguel Island, in California. He experienced undetermined physiological difficulties while submerging for his first dive of the day and was unable to resurface for help. After separating from his diving partner, he lost consciousness and could not be resuscitated after being rescued by the boat crew from the ocean floor. He was pronounced dead soon after being flown to a coastal hospital. Apart from drowning, a more specific cause of death has not been identified. Diving gave him great satisfaction—he had even shortened a consulting job in Canada to arrive in time to participate in the May 27 expedition. Always searching for new diving opportunities and locations, he used to joke by saying that when he was not diving he was planning dives. He was a frequent and careful diver, and had been diving about once a month during the two years preceding his death. Having dived with him on several occasions, this author knows well of Prof. Rusch’s prudence and attention to safety procedures. On Prof. Rusch’s part these factors are then not related to his death, which was an unexpected tragedy that deeply saddened his innumerable friends and colleagues throughout the world. He is survived by his wife of thirty-five years, Joann, one daughter, three sons, two grand children, his parents, one sister, and one brother.

The life of this outstanding man began in New York City, where he was born on July 12, 1933. Four years later his family moved to the Chicago area, where Prof. Rusch went to elementary school. His father, also an electrical engineer, worked with the Nielsen Company in the early days of radio ratings—he had several patents on the Nielsen audiometer, a device that registers the radio preferences of the listening audience. He attended high-school at George School, in Pennsylvania, graduating in 1950 as a Class Officer. George School, a Quaker founded boarding school, had a deep influence on his character, values, and hard-working habits. After the Second World War, in the summer of 1949, he went to a work-camp in war-torn Germany and participated in the rebuilding of a school. While in high-school Prof. Rusch had started to learn German, and this trip initiated what eventually became a life-long relationship with that country. Upon graduating from George School, he went to Princeton University where he

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Christmas Greetings

WE WANTED YOU TO KNOW HOW COMPLETELY WE BOTH ARE ENJOYING GRADUATE WORK HERE AT CALTECH IN BEAUTIFUL PASADENA. WE ARE STUDYING VLF RADIO PROPAGATION AND SHOULD BE BUSY SENDING RADIO WAVES OFF INTO SPACE FOR ANOTHER YEAR OR SO ALONG WITH OUR FELLOW NATIVE CALIFORNIANS.
WE EXTEND DEEPEST SYMPATHIES TO OUR FRIENDS IN EAST, BEST WISHES FOR THE HAPPY SEASON AND THE YEAR AHEAD.

Buddy and Bill

P.S. Big News is coming soon!

FIGURE 1. Christmas card sent by Prof. Rusch to his relatives and friends during his Caltech VLF antenna experiment days.

received his B.S.E.E. Summa Cum Laude in 1954, was the University Valedictorian, and was awarded, by the School President, the Milbank Prize. Prof. Rusch’s Princeton scholastic average was the highest of any previous Milbank Prize winner. The fundamental traits of Prof. Rusch’s personality and convictions are clearly present in his Valedictory Address, where he urges his class “…to base our lives in the premise that man, rather than material things, should be the center of our reality”[1]. After graduation he went to Caltech with a National Science Foundation Fellowship, married Joann in 1957, learned advanced electromagnetics from William Smythe and Charles Papas, and received a Ph.D. in Electrical Engineering in 1959.

Professor Rusch’s career in the field of Electromagnetics starts with the research work that eventually became his Ph.D. dissertation. Under the supervision of Robert Macmillan (Prof. Rusch was Macmillan’s first Ph.D. student), the characteristics of horizontal half-wavelength-long dipoles for VLF applications were investigated. The radiated field produced when such antennas are placed above a resistive ground was determined both theoretically and experimentally, and the corresponding results published in a series of articles and reports [2]–[6]. The interest in this antenna type stemmed from the fact that, when it transmits near the surface of an imperfect earth, maximum radiation is produced along the vertical direction, while creating a ground-wave null at a receiver located on the ground at the perpendicular bisector of the transmitting antenna. This makes this antenna well suited for ionospheric soundings, since a receiver located at the ground-wave null receives almost only the reflected skywave signal. In addition to cheerfully undertaking (as Fig. 1 indicates) part of the task of measuring ground resistivity at several Southern California locations, Prof. Rusch also worked on the design and construction of a 12.8 kilometers long version of this
VLF antenna, operating at 8.4 KHz. This half-wavelength antenna was made from an operational 60 Hz/12 KV commercial power line running along the Dinkey Creek Road near Shaver Lake, in California's Sierra Nevada Mountains [5], [6]. 8.4 KHz parallel-resonant circuits were inserted in both conductors of the power line, at both extremes and at the center of the 12.8 Km section, to electrically create a 8.4 KHz dipole without disturbing the 60 Hz line operation. A 20 KW 8.4 KHz signal excited the dipole center terminals through 8.4 KHz series-resonant circuits that simultaneously extracted 50 KW of 60 Hz current from the line to power the VLF transmitter. By taking advantage of an existing power line, located in a high-resistivity region, a useful experimental VLF transmitting station for ionospheric investigation could be constructed and brought into operation with modest budget. Although an estimated power of only 100 W was radiated, and the transmitter had a relatively poor frequency stability, the signal of the Dinkey-Creek station was detected as far as the east coast.

Prof. Rusch’s Ph.D. dissertation dealt with practically every aspect of the Dinkey-Creek antenna, including preliminary experimental VLF ionospheric propagation results [5]. Particularly interesting is Chap. II, which contains a general analysis of the current distribution on a linear antenna loaded with reactances, using Hallén’s integral equation. In it Prof. Rusch develops what he refers to as the matrix method solution—an earlier version of what is now known as the moment method with full-domain basis functions. Using an early Burroughs computer, Prof. Rusch tediously programmed his method with a rudimentary language called “semi-automatic coding scheme with simulated matrix commands” (the complete code is even provided in the Appendix II of his dissertation), and performed numerical simulations with up to 19 terms in his basis functions. Although the computer employed in the calculations limited the maximum number of terms to 52, Prof. Rusch demonstrated that in most cases ten terms yielded reasonable accuracy and proceeded to successfully apply his method to the Dinkey-Creek antenna.

After completing the Doctorate, Prof. Rusch spent a year in Aachen, Germany, in the company of his wife and son. He went there as a Fulbright Scholar with the Microwave Institute of the Technical University of Aachen, basically doing further work on the analysis of linear antennas, as indicated by the internal report he authored at that time [7]. He returned to California in September of 1960 to join the faculty of the Electrical Engineering Department of the University of Southern California (USC), starting the academic career that lasted until his premature death.

Professor Rusch’s initial research work at USC dealt basically with two distinct topics: interaction of electromagnetic waves with plasmas and millimeter-wave radioastronomy. On the first subject he focussed primarily on the radiation of electromagnetic waves by antennas located on a plasma-clad cylinder, a subject of great interest at that time due to its impact on spacecraft communication and detection during atmosphere reentry. He has a number of theoretical publications on this topic, most during the first few years of his academic career, Ref. [8] being a representative one. However, he gradually lost interest in this subject—his last paper on it was published in 1967 [9]. Prof. Rusch’s interests in millimeter-wave radio astronomy started around 1962, and were intermixed with the analysis and design of reflector antennas. In the end of 1962 he went to
the Radio Astronomy Branch of the Naval Research Laboratory, in Washington, to participate in the 13.5 mm wavelength observations of the Venus atmosphere being made in conjunction with the Mariner spacecraft mission. A detailed account of his participation in these observations is given in Ref. [10], where he writes fondly about “...the first antenna in the world suitable for planetary mm radio astronomy.”—a 3 meter diameter paraboloidal reflector with a peak surface accuracy of 0.1 mm. Ref. [10] is an interesting non-technical article, with some evidence of Prof. Rusch’s keen sense of humor in a few passages. He even mentions his finding of a spider web on the feed horn, “after a long day’s run of exceptionally rough” measurements.

Soon after joining USC Prof. Rusch began his pioneer contributions to the reflector-antenna field, regularly working as a consultant for the Jet Propulsion Laboratory (JPL) which was then initiating its reflector-antenna efforts in response to the space race. This started Prof. Rusch’s life-long affair with reflector antennas and produced his first paper specifically on the subject [11]. This paper was actually a byproduct of his seminal work on the scattering from hyperboloidal reflectors, which was initially published as a JPL technical report [12], and subsequently as the journal article that is now considered a classical work on reflector scattering [13]. In those days the evaluation of the two-dimensional scattering integrals present in the analysis of reflector antennas, in a reasonable amount of time, was beyond the capabilities of the available computers. Using the physical-optics (PO) approximation, in this work Prof. Rusch basically accomplished two objectives: rendering these integrals more tractable and verifying the accuracy of the PO approximation when applied to subreflectors. Taking advantage of the fact that the field radiated by most high-performance feeds is almost axially symmetric, he was able to evaluate the azimuthal integrals present in his problem in closed form, leaving only radial integrals to be handled numerically. This reduced the numerical integrations to a single dimension, bringing their computation time to a reasonable level. Using this method Prof. Rusch then proceeded to determine the electromagnetic field scattered by hyperboloidal reflectors. By comparing theoretical and experimental results obtained with subreflectors of 7.8 and 19.5 wavelengths in diameter, Prof. Rusch then firmly established the accuracy of the PO approximation for the analysis of subreflectors. Since his work was geared towards large Cassegrainian reflector systems, Ref. [13] also contains a preliminary discussion of the impact of diffraction effects on the overall antenna performance, as well as the analytical transformation of the scattering integrals into the corresponding geometrical-optics results.

In 1963 Prof. Rusch became an Associate Professor and started working on the construction of a complete millimeter-wave radio telescope. Cleverly taking advantage of the availability of Second World War surplus equipment, Prof. Rusch acquired a searchlight with support from JPL and a Joint Services grant, and modified it into a 90 GHz radio telescope [14]. A 19 cm diameter subreflector was added to the 1.5 m diameter paraboloidal reflector, transforming it into a Cassegrainian antenna to allow the associated diagonal feed horn and electronics to be mounted immediately behind the main reflector. Several other modifications were made, including the addition of synchronous driving motors and optical telescopes for accurate pointing and tracking of celestial sources. The receiver section of the radio telescope was developed at the JPL under the supervision of Charles Stelzried, who also participated on the radio-
telescope development and subsequent observations. Figure 2 shows a picture of the radio telescope, and corresponding preliminary radiation pattern, taken during its development. By the end of 1963 the radio telescope was ready for operation and was successfully used to measure the temperature of the moon during the December 30th eclipse [15],[16]. A state-of-the-art instrument for those days, it was capable of an estimated 3 K sensitivity at 90 GHz, when operated as a Dicke radiometer. Work on the improvement of this radio telescope, and its utilization on other radio astronomical observations, continued until 1969 [17]. Part of the reflector development even became the Ph.D. dissertation of Stephen Slobin, who graduated in the beginning of 1969 and was involved with the project since its inception. Slobin was the first Ph.D. student of Prof. Rusch. His dissertation dealt with Cassegrainian antennas with a nodding subreflector and their application to radio-astronomical observations. As part of his dissertation the nodding system was implemented and tested in the searchlight radio telescope.

During the searchlight radio telescope development Prof. Rusch worked with diode mixers, and was repeatedly made aware of their dominant role on the sensitivity of the receiving system. Partially motivated by this, in 1966–1967 he went with his family (now with four children) on a one-year sabbatical leave from USC to work with solid-state diodes at the Bell Telephone Laboratories in Holmdel, New Jersey. His work during this period ultimately proved to be a detour from his main interest areas, and he never returned to it after the sabbatical. The results of his research at the Bell Laboratories are described in Ref. [18].

After 1969 Prof. Rusch’s work concentrates primarily on reflector antennas, with sporadic excursions on radio-astronomical subjects. In addition to Slobin, in 1969 he also graduated two other Ph.D. students, Arthur Ludwig and Charles Stelzried. The first with a dissertation on reflector antennas and the second with one on Faraday rotation. Both dissertations were also published as JPL technical reports since, in addition to
the fact that they were both JPL employees, their dissertation work was also done in collaboration with JPL [19],[20]. Ludwig's dissertation dealt with the evaluation of the field scattered by reflector antennas and introduced his now famous integration algorithm. Stelzried's dissertation dealt with 2.292 GHz polarization-rotation measurements, made when the Pioneer VI spacecraft was occulted by the sun in 1968. The then recently built JPL Goldstone 64 m Deep Space Network Cassegrainian antenna, which was designed using many of Prof. Rusch's antenna analysis tools, was used for the experiment. Fig. 3 is a photograph taken about the time of these measurements.

In 1970 Prof. Rusch published his classic book "Analysis of Reflector Antennas", which was co-authored by Philip Potter [21]. With it they made available, for the scientific community, what is basically the knowledge accumulated in their ten years of work developing large reflector-antenna systems for the JPL Deep Space Network. Shortly after the publication of his book Prof. Rusch started doing consulting work regularly for TRW. His association with this company later intensified, and lasted until his death. The results of some of his initial work there, dealing with defocusing effects on paraboloidal reflectors and the analysis of umbrella reflectors, can be found in Refs. [22] and [23].

Professor Rusch became Professor of Electrical Engineering in 1972 and in the subsequent year went with his family to Denmark, to spend a one-year sabbatical leave at the Electromagnetics Institute of the Technical University of Denmark, in Lyngby. His Denmark year left fond memories—in countless occasions this author heard remarks indicating it. There he lived in a house once occupied by Hans Christian Andersen, the fairy-tale master, did electromagnetic research, and taught antenna classes. The notes that he put together for the classes were published as a two-volume internal report with more than 400 pages [24]. The first volume deals with fundamental aspects of antenna theory and ends with an introductory coverage of the method of moments technique. The second volume concentrates its over 200 pages on reflector antennas.
and their associated analysis techniques. These two reports constitute a very comprehensive antenna book, even though Prof. Rusch never felt compelled to publish them as such.

The year spent in Denmark was very productive and yielded a number of publications in collaboration with the Danes [25]–[29]. The last reference is particularly noteworthy, since it was the result of a number of years working on the problem of modeling the effect of supporting struts on the radiation characteristics of reflector antennas. This particular problem had been around Prof. Rusch since the very start of his JPL consulting work, and was even the subject of a technical report a few years earlier [30]. In Ref. [29] Prof. Rusch presented his Induced Field Ratio (IFR) method, which allows the antenna engineer to combine accurate scattering results of infinitely-long struts with most available reflector-antenna scattering evaluation techniques. The IFR method is based on the IFR hypothesis, which states that the current induced on long (but of finite-length) struts can be approximated by the currents induced on the corresponding infinitely-long struts. With this technique the reflector-antenna radiation characteristics, including the strut effects, can be accurately determined for simple strut geometries. In a subsequent article the method was applied to determining the radiation cones produced by the struts on the reflector-antenna radiation pattern, and the results compared with measurements made on the The Netherlands Dwingeloo telescope, confirming the excellent accuracy of the IFR technique [31]. The IFR hypothesis is not applicable to complicated strut geometries (e.g., truss struts), and to this day no completely satisfactory method has been developed to handle such cases. However, even in such cases the IFR technique developed by Prof. Rusch can be used to provide approximate results, and hence still stands as one of the best available tools for determining the electromagnetic effects of supporting struts.

In recognition for his many contributions to the reflector antenna field Prof. Rusch was elected Fellow of the IEEE in 1975. In 1977 and 1978 he graduated two more Ph.D. students, Mohammad Rahnnavard and Frederick Young, respectively. The first with a dissertation on surface-induced microwave shadows, a phenomenon that may occur, for instance, on the subreflector of Cassegrainian antennas shaped for maximum gain [32]. In these geometries the subreflector may have an inflection point that creates a caustic along the reflected rays, at the observation point of interest, creating singularities when geometrical optics is used to determine the subreflector scattering. Rahnnavard’s dissertation studied this problem and derived appropriate correction techniques. Young’s dissertation dealt with the analysis and design of toroidal reflector antennas with aberration-correcting subreflectors [33].

Around 1977 Prof. Rusch intensified his consulting work at TRW, being there the equivalent of almost two days a week during the regular academic year—a pace he kept until shortly before his death. Most of the work performed for TRW was never published in the open literature, due to commercial and security restrictions. Among the material that was published is part of his work on the blockage produced by linear antennas when they are used to feed reflectors, which was done in conjunction with TRW's effort on wide-band reflector antennas fed by log-periodic dipole arrays [34]. Also published was a very small part of his work on umbrella reflectors, Refs. [23]
and [35]. On this last subject Prof. Rusch was active until shortly before his death, providing TRW with advanced software to analyze and design single and dual umbrella-reflector antennas, fully accounting for practically all relevant parameters, including mechanical surface distortions and mesh reflectivity characteristics. This author is familiar, to a certain extent, with Prof. Rusch’s consulting work on umbrella reflectors because, in addition to the fact that this was his Ph.D. dissertation topic [36], he was also involved in some of the TRW projects.

In the 1980-1981 academic year Prof. Rusch took another sabbatical leave, this time at the Max-Planck-Institut für Radioastronomie in Bonn, Germany (this was his last sabbatical leave). He went there as a Von Humboldt Senior U.S. Scientist, to work with the 100 m diameter radio-astronomy reflector located near Effelsberg—the largest fully steerable reflector antenna in the world. After many years away from radio astronomy antennas, this trip was a return to one of Prof. Rusch’s early research interests. Fig. 4 shows Prof. Rusch and his wife Joann near the Effelsberg antenna. At the Max-Planck-Institut he continued his work on reflector antennas and developed electromagnetic analysis tools for the 100 m radio telescope. A number of publications resulted from his interaction with the Max-Planck scientists, Ref. [37] and [38] being two representative ones. While in Germany Prof. Rusch also prepared his first invited review paper on the state of the reflector-antenna art, for the IEEE Transactions on Antennas and Propagation [39]. Eight years later he was again invited to write another one on the same subject, which was published just a few months before his death [40]. Prof. Rusch kept in contact with the Effelsberg telescope group after his return from Germany, collaborating with them in several subsequent occasions. His last work with them deals with a very small (2 arc-second) beam squint effect observed when the 100 m antenna is used with a scanned feed operating with circular polarization [41]. The squint is caused by cross-polarization effects, and was both measured and confirmed theoretically, demonstrating once again the excellent accuracy available from the antenna analysis techniques that Prof. Rusch helped develop throughout his prolific career. On his return from Germany Prof. Rusch graduated his sixth Ph.D. student, Dau-Chyrh Chang. Chang did his research on the analysis and design of offset dual-reflector antennas with axially-symmetric main reflectors [42]. This work exploited the fact that a high-performance clear aperture antenna can be produced using an axially-symmetric reflector excited off axis, provided that a suitable (non-axially symmetric) subreflector is properly designed to compensate the phase aberration introduced in the process. The advantage of such system lies in the reduced cost of the axially-symmetric main reflector, when compared to a standard (non-symmetric) offset reflector. As Ref. [42] indicates, good results were obtained with this new antenna.

Since the early JPL consulting days Prof. Rusch recognized the need for exact (in a numerical sense) reflector-antenna analysis tools, since in many instances it is advantageous to have the capability to exactly emulate practical experiments. In response to this, in 1971 he did preliminary work on the topic [30]. However, in those days of limited computers he was only able to handle two-dimensional problems, and could not tackle more practical reflectors. He returned to the subject more than a decade later, when computers finally became sufficiently powerful, working with David Jenn in his Ph.D. Dissertation topic. Jenn graduated in 1987 with a Dissertation that finally
modelled exactly, including the supporting struts, three-dimensional reflector antennas [43]. Using a CRAY computer Jenn was able to analyze, using the method of moments, single- and dual-reflector antennas employing paraboloidal main reflectors of small diameters. With this he was able, among other things, to once again confirm the accuracy of many of the techniques that Prof. Rusch help develop in his many years working on the antenna field (e.g., PO, IFR, etc.). The research along the line of exactly modeling reflector antennas proceeded with Michael Barclay, who completed his Ph.D. in 1990 under Prof. Rusch’s supervision. Using entire domain basis functions Barclay was able to analyze large axially-symmetric antennas [44]. In addition to this, his formulation was also capable of handling reflectors coated with lossy dielectrics, a feature that he successfully used to synthesize radiation patterns with low sidelobe levels [45].

In the beginning of 1989 Prof. Rusch started doing research on the time-response of reflectors excited by non-harmonic signals, in conjunction with the Ph.D. Dissertation of En-Yuan Sun, who graduated in 1991. This work, which was geared towards the transient analysis of reflector antennas for ultra-wide-band radar systems, is still in progress at USC. Sun’s dissertation investigated the capabilities of the PO method, reformulated for the time domain, by implementing several other techniques, applying them to reflector antennas, and comparing the obtained results [46],[47]. At the time of his death Prof. Rusch was supervising another Ph.D. candidate, Allen Wang, in another dissertation along the reflector-antenna transient subject. Prof. Rusch left Wang’s Dissertation well advanced, and this author is currently supervising its conclusion. Prof. Rusch’s last Ph.D. student was Changcheng Yang, who did a Dissertation on the subject of shaping three-reflector antennas with axially symmetric main-reflectors [48].
This work developed the required numerical tools to produce an almost arbitrary field at the antenna aperture, thereby removing the amplitude restrictions present when only a single subreflector is used [42]. Yang demonstrated the capability of the method by synthesizing Taylor patterns with low sidelobe levels. Prof. Rusch died while Yang was in the final stages of writing his dissertation. However, he officially completed his work, on August 4, under Prof. Rusch supervision.

During his 32 years with the USC faculty Prof. Rusch taught numerous undergraduate classes on circuit theory, basic electromagnetics, numerical methods, and computer programming, and graduate classes on antennas and advanced electromagnetics. This author started his Ph.D. studies at USC in 1984, under Prof. Rusch’s supervision, and had the privilege of attending Prof. Rusch’s graduate classes on the last two subjects. He was an extraordinary teacher, and all his classes were much more than just lectures on technical subjects, for they also taught (unintentionally perhaps) the art of teaching. Prof. Rusch was always well prepared, presented the subject in a fresh manner, and was never dull. Attending his classes was always a pleasant and positive experience. He believed that it is only possible to learn through hard work, and hence provided the students with a consistent work load. In all the years that this author was associated with him, first as a student and then as a colleague, there was never a problem assigned in class that Prof. Rusch had not attempted ahead of time—he had great respect for the students and their time. He made every effort to make learning an enjoyable experience, and to this effect every one of his antenna analysis lectures had his trademark, the “show & tell:” in the beginning of each lecture, and sometimes also in the middle, Prof. Rusch discussed some practical antenna hardware, with detailed pictures, models, and many times the antenna itself. He was an engineer teaching engineers, and received innumerable teaching awards for his outstanding work. On going through his class evaluations, left in his very organized files here at USC, countless times one reads student comments praising him as the best teacher they ever had. He was the best teacher this author ever had.
Throughout his entire career Prof. Rusch had only eleven Ph.D. students. All their names and corresponding Dissertation topics have been mentioned in the previous paragraphs, since they are also part of his legacy. He did not accept many Ph.D. students to supervise, for he always wanted to be able to interact well with them. It is truly a privilege to have been his student. Two years after his death we feel fortunate that, in 1991, on his 58th birthday, we all showed our appreciation by surprising him with a dinner party in Pasadena.

In 1977, when Prof. Rusch achieved the rank of Professor, he also became the Director of the School of Engineering Undergraduate Honors Program. This program encourages academic excellence, and admission is based on the student’s academic record—only the top 4% of USC’s engineering undergraduate students belong to it. Basically the Program consists of a weekly colloquium, presented by a leader on his field of specialty, and an yearly weekend retreat. Members of the Program are also allowed additional freedom in selecting their courses. Under the leadership and enthusiasm of Prof. Rusch—who once mentioned to this author that he considered his involvement with the Honors Program the great contribution of his professional life—this program flourished into a first-rate USC institution. The impact of Prof. Rusch on the Honors Program members can be felt on their farewell message to him, which was posted, at the time of his death, on the Honors Program sign board (see Fig. 5). A few months after Prof. Rusch’s death, in an unprecedented display of affection, respect, and admiration, the Honors Program students forwarded to the Dean of the School of Engineering a petition, signed by nearly all of its members, requesting the renaming of the Honors Program after Prof. Rusch. Their request was attended, and USC now has the W. V. T. Rusch Undergraduate Honors Program. No other tribute would have been appreciated more by Prof. Rusch.

In the above paragraphs an attempt was made to summarize Prof. Rusch’s scientific and academic history. However, due to unavoidable space restrictions and lack of available records, many of Prof. Rusch’s contributions were left unmentioned (even the references provided below are far from exhaustive). In an effort to partially compensate
for this and other omissions, the readers are referred to Fig. 6 which, perhaps, will say more than any words.

In writing this article the author had the invaluable assistance of the family, friends, colleagues, and former students of Prof. Rusch. Their prompt reply to numerous questions and requests, which were essential to the preparation of this article, is gratefully acknowledged. On a more personal side, this author is very grateful to the Rusch family, for their many years of close friendship.

References


