Yesteryear—Tomorrow

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IT IS an exciting experience for an individual to participate in the birth of a new technological discovery and then to live to see it develop from infancy into a mature and important factor in the world. Such an experience comes unexpectedly to only a few lucky individuals and then usually once in a lifetime. I have always considered myself fortunate to have shared this kind of experience with a few other fortunate persons in the opening up and growth of the modern microwave industry.

Classical electromagnetic theory was established by Maxwell and transmission and reception at microwave frequencies had been demonstrated by Hertz prior to the year 1900. Nonetheless, the practical possibilities of this region of the spectrum were not appreciated during the early part of the twentieth century. Interest, development, and commercialization were then completely in the lower frequency region. Those of us who directed our scientific careers at that time toward the vacant land of microwaves had to go it pretty much alone.

There was, of course, good reason for the lack of interest and activity in the applications of microwaves. Although there were a few ideas that certain applications would be worthwhile, such as point-to-point communication and aids to air navigation, certain others could not be fully visualized, or if foreseen, could not be properly evaluated. But a really practical solution seemed far away indeed.

There were no satisfactory generators of microwave power. The receiver art was no further advanced than that of the simple detector. Means of conducting energy about, or of radiating it into space, or receiving it, were in a preprimitive state. And the equivalents of circuit elements, bridges, filters, and so on, that make sophisticated communications systems possible, were totally missing. Thus, a complete new technology had to emerge in order for the many applications to change from the dream stage to one of practical and economic reality.

The decade from *1930 to 1940* might well be termed the *Period of Discovery* of the modern microwave technology. It is largely in this period that the basic contributions were made on which later progress was built.

How did one get started in this Period of Discovery of microwaves? I had best give you some personal experiences here, but I suspect that the situation was more or less the same for Southworth, Schelkunoff, Hansen, the Varians, Hahn, Metcalf, Wolf, Chu, and the others.

Firstly, there was *the scientific urge*. For me, this was a burning desire to understand thoroughly and basically the theory of radio wave propagation. I am sure that such a personal urge must be present in anyone who undertakes Columbus-like voyages into uncharted and unpopulated technological areas.

Secondly, there was *the preparation*. More than the teachings of undergraduate courses was necessary. It did not appear, when my education was under way, that the teaching of electromagnetic theory was done nearly as well in the United States as it was in Germany. Thus, it was that I went to the latter country to study under Zenneck and Sommerfeld. Today, or at any time, a sound and careful preparation is a necessary task for anyone who sets his sails on a voyage of discovery. It may be carried out in any of several ways, but certainly today more than ever before, a sound theoretical background is necessary for advanced work in microwaves.

Finally, there was *discovery productivity*. Back at M.I.T. in 1931, the problem of why electromagnetic waves could not be sent from a horn of metal—the corresponding device to an acoustical horn—appeared to me to be an important unanswered scientific question. The first attack on this problem was theoretical and because of the complexities, no solution was obtained immediately. However, these efforts suggested the query as to why could not electromagnetic waves that might radiate from the large end of the horn be led into its small end through a conducting hollow metal pipe—corresponding to an acoustical speaking tube. The mathematics here were easier and in 1932, the answer was found to be *yes*, they could be transmitted through a pipe with finite losses, provided a certain critical frequency was exceeded. Shortly, thereafter, the horn problem also gave a favorable answer.

Today, it is hard to realize that at that time only a few individuals were prepared to accept the reality of waveguide transmission and horn radiation, largely because of the absence of a second conductor, theretofore considered essential in any electrical circuit or transmission line. It was clear that a demonstration would be necessary before much attention could be attracted to this new transmission technique.

It proved to be harder to demonstrate than it had been to solve the mathematics. There followed a waiting period during which the development of suitable power sources took place. W. W. Hansen and his colleagues at Stanford University were then laying the groundwork for successful microwave amplifiers and oscillators. Finally, in March, 1936, the first experiments were performed at M.I.T. in a cast-off galvanized-iron air duct 18 inches in diameter. By this demonstration the earlier theoretical conclusions were confirmed and a new tech-

nology for handling microwaves was opened up. The period of discovery was now well under way.

During this same time, Southworth and his associates at the Bell Telephone Laboratories had been striving for the same ends industriously, effectively, and quietly. With the greater manpower and facilities available to them they made an even greater contribution than we did at M.I.T. to pioneering this new technique, and were often ahead. I feel sure, however, that dismay was equally shared when each first learned that the other was scheduled to present his first paper on the subject at the Spring Meeting of the IRE and the American Physical Society in Washington, D. C. on May 1, 1936. This emotion was promptly dissipated by a cordial pre-meeting interchange of papers that was but the beginning of continued close and friendly relations.

The early days at M.I.T. were characterized by simple equipment and modest effort. For example, the first several years of work were done with about $100 a year and to a great extent on "extra-curricular" time. Think what a small effort that would be today! It was important for its future growth that this infant technology get into the hands of many others and that real "push" be put behind it.

This push was supplied by wartime necessity. The need for microwave airborne and gun-laying radars supplied almost unlimited manpower and funds. The M.I.T. Radiation Laboratory was organized as a governmental activity and several commercial organizations such as Sperry Gyroscope, General Electric, RCA, Raytheon, and many others, either expanded their efforts greatly or joined the parade. The results were astounding, and every branch of microwave technology advanced rapidly beyond the fondest dreams of the Period of Discovery.

Thus, starting with the World War II effort we might designate a *Period of Development* of microwaves. Mathematicians, physicists, and engineers in considerable numbers and with great talents have developed this field into a highly sophisticated science supported by a vast amount of engineering know-how. Applications now encompass line-of-sight and scatter communication links, marine and air transport navigation and weather radars, particle accelerators for research, medical, and industrial uses, equipment for measuring the properties of materials and controling industrial processes, and many others besides. The modern microwave specialist has available an extensive array of power sources, test equipment, resonators, fixtures, and plumbing components. He employs elaborate and advanced procedures and methods of construction that make him among the most competent of contemporary engineers. He may even consider that his is a separate profession.

The frontier that was invaded in the early 1930's has only been pushed back, not vanquished. There is still virgin ground to be explored by the daring and significant contributions to be made by the industrious. Preceding editorials by G. C. Southworth and Ernst Weber have illuminated very well the future technical challenge that lies ahead.

Within the industrial complex surrounding contemporary microwave specialists are other rewarding opportunities for personal growth. I refer to the opportunities for men with technical backgrounds in executive and managerial positions. The need for individuals possessing both technical and administrative abilities is now great and it will become even more so in the expanding future of our profession. Although it is easiest to move into technical administration, there are other attractive avenues. Manufacturing, sales, and management in many of our companies, both small and large, also offer exciting and rewarding challenges to the exceptional individual ready to risk another kind of exploratory voyage on the industrial sea.

The horizon of the microwave professional of today is indeed wide and enticing. It would be wonderful to start all over again.