# 1987 IEEE MTT-S International Microwave Symposium Keynote Address

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WELCOME TO THE MTT 1987 Symposium! Before I begin my presentation, I would like to mention that I agree wholeheartedly with Bruno Weinchel's statement that the United States needs to focus on production-oriented training of engineers instead of just rewarding and recognizing those who work in the R&D environment. Through my teaching experience, I have discovered that most American engineers will generally spend a great deal on the theoretical design of products and then see if their "nominal" design can be manufactured (the sad truth is that less than 5 percent of microwave engineers conduct some form of yield analysis to estimate what can be expected in a realistic production environment). Foreign-trained engineers, however, seem to concentrate more on designing products that can be manufactured economically. So, I would encourage industry, academia, and IEEE to concentrate on creating and adding meaningful production-related courses to both graduate and undergraduate curricula.

My talk today will examine several pioneer engineers in the microwave industry. Choosing key people for this talk proved a very difficult task. I finally selected a person, or in some cases two individuals, to represent each decade, starting with 1930's. I want to apologize to those who do not appear in my list, but as I mentioned, I had a difficult time selecting among so many qualified people. (I know how unjust some of you must feel this is; I have the same reaction every year when the IEEE Fellow selections are announced.)

Going back to the 30's, I want to focus first on Phillip Smith, who graduated at the top of his class from Tufts University in 1928 and immediately started working for Bell Laboratories. (He was a radio amateur, extremely good with his hands, yet a very practical person.) His first assignment involved shortwave overseas radio transmission lines and antennas. He wanted to replace the complex transmission line equations with some kind of visual aid, so that designers would not have to deal with the related mathematics.

By 1931, he had completed his Chart concept, although it took several more years before the first working model was in use. In 1936 he began using the Chart in his own work, and he later explained its operation in two articles. The first paper, in 1939, explained the basic principles, while the second one, in 1944, dealt with special versions and applications of the Charts (expanded and compressed versions). The Chart became extremely popular once it was introduced; it is still widely used in manually oriented circuit design, computer aided circuit design, measurements, and education. To illustrate the popularity of the Chart, an estimated 20 million of them have been distributed during the past forty years.

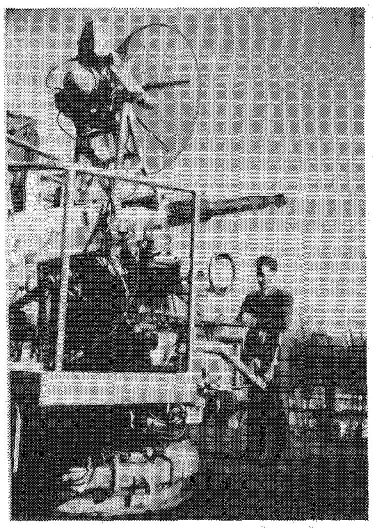

Fig. 1. Phillip Smith pictured during WW II with a Navy radar installation.

During World War II, Phil concentrated on radar antennas (see Fig. 1). After the war he worked with FM broadcast antennas and commercial applications. Then, in 1946, he invented a new concept called the Cloverleaf-type antenna.

As his expertise in military systems became recognized, he was given opportunities to work on the DEW lines, Nike-X, and the Safeguard systems. He worked extensively on a major antenna system for the Island of Kwaj, using the Lunenburg Lens principles.

Phil was also a pilot. He loved to fly his Cessna, but according to his family, he was a much better engineer than pilot. His wife, Anita, was not very enthusiastic about flying with him because of several close calls. I understand that when she was pregnant, she simply refused to go up with him and eventually put enough pressure on him so that he sold his plane.

In the late 60's, Phil, working with Kay Instruments, compiled a series of application notes on the Chart that was eventually condensed into a book. Kay Instruments released the Chart's printing plates to Phil and allowed him to do the commercial marketing. He formed a company, Analog Instruments, whose main purpose was to provide graphical aids to microwave designers—primarily the "Smith Charts."

Phil retired from Bell in 1970 so that he and his wife could devote themselves to their own business. Unfortunately, not much later he was diagnosed as having Parkinson's disease, and he has been hospitalized since 1980.

As I talked with Bob Maddingly, who was Phil's supervisor at Bell Labs, he described Phil as an "intuitive, hardworking, and, perhaps even more important, rare human being who had no enemies. He was very popular and was liked by his peers." Phil's daughter, Penny, also decided to become an engineer. Graduating last year, she now works for Litton Airtron as a microwave engineer. Her plans include graduate school in the near future. When I asked what motivated her to enter the field of engineering, she said, "Well of course it was my father. He always helped me with math and was very good in problem solving."

To summarize, Phil has made a tremendous contribution to the field of microwave technology by simplifying complex mathematical problems. In addition, he is a special person whom we deeply appreciate.

Moving into the 1940's, I would like to highlight the success story of two men who first met a Stanford and later decided to form a company. Even though they were not microwave engineers originally, I chose to describe their story because of their contribution to the field of microwave instrumentation. I think by now you can tell that I am referring to Bill Hewlett and David Packard.

Very few people realize that Hewlett and Packard were not commercially successful with some of their earlier inventions, such as foul line indicator for bowling alleys, a weight-reducing machine that provided electrical shocks while the user was eating, and a urine flusher system. Perhaps if these ideas had been commercial hits, we would not have network and spectrum analyzers today.

Their first successful product, an audio generator using a light bulb to improve oscillator stability, was created from Bill Hewlett's graduate project at Stanford. Frederick Terman, their electrical engineering professor, recognized the significance of the innovation and suggested that they produce the generator commercially. Bill and Dave's friend Norman Neely persuaded a fellow engineer to use the audio generator to produce the special sound effects in Walt Disney's *Fantasia*. Disney went along with the idea and purchased eight of the generators. Norm drove to Los Angeles in his tomato truck to deliver the generators, and the success of Hewlett-Packard Company was ensured. Norm Neely is no longer driving a tomato truck, and both Hewlett and Packard are billionaires as a result of their innovative efforts. The famous Palo Alto garage where their ideas took root is now a landmark in the San Francisco Bay Area.

Hewlett and Packard, whose company grew rapidly during World War II (about a hundred people were on the payroll in 1946) were both skilled engineers (see Fig. 2); however, Hewlett concentrated on engineering problems while Packard focused more on the business aspects. Their close friendship was based on similar philosophies and mutual compatibility (although the story goes that one morning Packard announced an early-morning staff meeting for 8:00 a.m. At 8:15 staff members were still wandering into the room. Packard, increasingly annoyed, made a loud statement as he heard the next person approaching the door: "The next person who walks through the door should not be part of this team!" Of course, it was Bill Hewlett, but I suppose he was forgiven since he remained on the team).

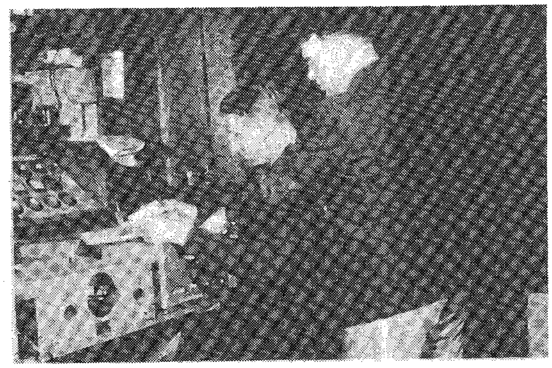

Fig. 2. David Packard (seated) and Bill Hewlett testing one of their early instruments in 1945.

After World War II, when Bill Hewlett returned from active duty in the Army Signal Corps, the decision was made to enter into microwave instrumentation. Hewlett and Packard brought in two extremely capable microwave engineers: Bruce Wholey, who had graduated from Stanford with a microwave background from Radio Research Labs at Harvard, and Art Fong, a University of California (Berkeley) graduate with a MW background from MIT Radiation Labs. With the assistance of these two men, the company quickly formed a team that soon rivaled General Radio's. This team developed a line of signal generators from 50 kHz to 21 GHz as well as such components as slotted lines. As its products gained in acceptance, HP set new standards in the industry.

Art Fong's strong interest in radar led him to recommend the production of a police radar, and he eventually developed a prototype. However, he was reminded that HP was in the business of measuring electrical quantities, not the speed of cars. Successful products such as sampling oscilloscopes, spectrum analyzers, vector voltmeters and network analyzers allowed microwave engineers to use new measurement techniques to accelerate the design of new equipment.

Since the 1970's HP has become more of a computer company. The transition started with its model 9100, a desk-top calculator, in 1968. Barney Oliver, vice-president of engineering at the time, supervised the calculator's development. The 9100 was first sold for $5,000. Hewlett, who was impressed, commented jokingly that he would like to see it fit into his shirt pocket. Oliver said it could be done and took the task so seriously that he measured Hewlett's pocket to be sure that the calculator would fit. This was during the time when Packard was in Washington, D.C., acting as Assistant Secretary of Defense.

When he returned to HP, he was genuinely worried that such a calculator, selling at $400, would not be a saleable item. He estimated that he would need 10 000 units to break even during the first year of sales. As it turned out, 100 000 "pocket calculators" were sold, and HP became firmly established in the calculator/computer business.

What makes this company unique is the so-called "HP Way" philosophy. The company offers a pleasant working environment to its staff by assuming that people are committed to doing a good job in their area of expertise and will sound decisions; by using management by objective (MBO), ensuring a lot of freedom; and, perhaps the most important part, by employing an open-door policy. Management was always accessible, and expert help was available within the company.

I will never forget my experience as a fledgling engineer at HP. I needed help with the product I was developing and was referred to an expert who worked in a different division. Although he was extremely busy, he spent many days instructing and encouraging me. I did not fully appreciate his collegial attitude until I left Hewlett-Packard. I discovered very quickly that sharing knowledge with co-workers was not a general practice in the industry.

Hewlett and Packard also played very important roles in government activities, civic education, and professional groups. In conclusion, the result of their unique effort was the creation of the very personable, friendly company that is now one of the largest and most successful in the world.

Moving on to 1950's, we find two men who recognized the electronic needs of the defense industry. Dean Watkins and Richard Johnson first met at Hughes Aircraft while working on TWT's, of which Watkins was the coinventor at Stanford. They both wanted to own their own business, but the same problem that has stopped many entrepreneurs from starting companies faced them, too: they didn't have any money.

Again, as in many other instances, Frederick Terman intervened by arranging financing through a local company interested in electronics investments. A $900 000 capital investment launched the company in Palo Alto. During its first year, it showed profit. The company' products were primarily traveling wave tubes, parametric amplifiers, and backward oscillators (see Fig. 3). Its unique contribution was the combining of tubes with power supplies. Beforehand, tubes were sold as an individual item, leaving the design engineer with the problem of biasing details. Quite often a project would fail due to the lack of a proper power-supply attachment.

Watkins-Johnson made many wise acquisitions that allowed extremely rapid growth. It purchased Stewart Engineering, which was in the backward-oscillator business; Communications Electronics, in the receiver business; RELCOM, in the mixer business; and the antenna lines of Granger. It showed foresight by investing in solid-state and MIC facilities in the 70's, when TWT replacements took place.

WJ also recognized that to sell something, it must enter that field very early. (This was demonstrated to the company through one failure; it had a hot–cold load machine to measure extremely low noise figures, but was unable to market the machine because it was not in the instrumentation business.) WJ entered the space program, established foreign business offices, and eventually got into the total turnkey systems.

Fig. 3. Dean Watkins discusses TWT operation with Prof. Fredrick Terman of Stanford University in the early '50s.

In the late 70's, when most companies cut back because of the slowing of the space program, Watkins-Johnson maintained active recruiting. This decision really paid off in the early 80's, when defense needs were again increased. Watkins-Johnson, with its strong staff, was readily available for production capability.

When asked about successful company policies, Dean Watkins said that they preferred hiring young people directly from school and that most promotions are made from within the company, thereby giving people a good chance for advancement and thus an incentive to work harder. They also encourage delegation of authority with one exception: whenever possible, either Watkins or Johnson still personally interviews the engineering candidates.

In summary, WJ is a no-nonsence company based on technical excellence. As Dean Watkins has said, "We give all the opportunities to our staff, and if they don't succeed, we simply ask them to go elsewhere."

The next person is a unique individual—Austrian by birth, British by adoption, and American by choice. He is Leo Young, who lived in Vienna with his parents prior to World War II. His father later received a job offer in England, where the family decided to make its home. At the age of 16, Leo applied for and received a scholarship from Cambridge University. He received his first degree, in mathematics, by his 19th birthday, and by the age of 21 he earned a second degree, in physics. In 1948 his first job assignment was to draw a box for an oscillator. He did not have any idea how to draw, nor did he know very much about oscillators. However, he learned both engineering and circuits very quickly. His next job was with a microwave company, and from then on he stayed in the microwave industry.

In 1953 he accepted an offer from Westinghouse Electric Corporation to come to the United States. He was newly married at the time and talked the offer over with his wife, who was just completing her master's degree in psychology. The timing was perfect, and they set sail for the New World to start married life here.

I should mention something interesting about Leo and his wife. He was a physicist and she was a child psychologist. During their wedding, the minister asked him jokingly is this was a marriage of "mind over matter?" (I guess they had more than a meeting of the minds as they soon had three children.)

While he was working at Westinghouse, he went to graduate school part-time, and in 1958 he received the prestigious B. C. Lamme scholarship to the Johns Hopkins University. This scholarship is awarded annually by the Westinghouse Electric Corporation to one of its outstanding engineers. Leo Young had visualized a connection between two seemingly unrelated papers: one on filters by Seymour Cohn and one on transformers by Henry Riblet. He then chose as his dissertation topic quarter-wave transformer theory applied to filter design, and he subsequently developed a strong interest in microwave filters. He saw the need for a comprehensive book and submitted an outline to a publisher. The draft was reviewed by Seymour Cohn, who was very impressed by Young's ideas. He told Leo that similar work was being considered at SRI and suggested a collaborative effort. Leo accepted the offer and came to SRI in 1960. In 1964, together with George Matthei and Ted Jones, Young published the famous "microwave bible." The comprehensive book, *Microwave Filters, Impedance Matching Networks, and Coupling Structures*, deals with microwave circuits and transmission lines, both in a tutorial and handbook fashion.

In 1963 he received the Microwave Prize and in 1968 was elected to be National Lecturer. In 1972 he edited two significant books, *Parallel Coupled Lines and Directional Couplers* and *Microwave Filters Using Parallel Coupled Lines*. These books have also become extremely popular. In 1973 he was invited to join the Naval Research Laboratory (NRL), where he became Associate Superintendent of the Electronics Technology Division. In 1981 he transferred to the Office of the Secretary of Defense, coordinating the R&D efforts of all the armed forces. This job includes overviewing basic research, university and small business relationships. He has recently become more interested in engineering for manufacturing and equipment support (or logistics) and is currently responsible for DOD's, R&D programs in that area.

Leo has been heavily involved with IEEE and has held many offices, including Chairman of the MTT-S AdCom, served on the Board of Directors (see Fig. 4), and eventually became President of the IEEE in 1980. He was one of the first individuals who felt that professional societies should not confine their activities to just technology. By that time, there were an estimated million engineers in the U.S., with comparatively little political or economical influence as a group. Leo felt that IEEE, as its title implied, was a society of and for engineers (not just engineering), and should assist engineers in all their professional problems. With the help of like-minded members they convinced the IEEE Board of Directors to change the Institute's constitution accordingly, and in 1972 the new constitution was approved by the memberships with 87-percent in favor. It is very interesting that a man who left England seeking better technical opportunities, became head of the largest engineering association in the world. And I felt very comfortable seeing him in that position we could not have had a better man for the job.

Fig. 4. Leo Young (second from right) discusses IEEE policies.

Entering the 1970's, miniaturization became a very significant issue due to the space program, resulting in the necessity to bring device and circuit designers together. This was a very difficult task, because generally these two groups came from different backgrounds, used different buzz words, even different dimensions and units. Perhaps the first person to combine these different areas of expertise was Charles Liechti.

By 1970, IBM and Fairchild had done research on GaAs FETs and produced reasonably good gain at microwave frequencies but could not reduce the channel noise in these devices. Relatively new at Hewlett-Packard Laboratories, Charles recognized the impact GaAs transistors might have on microwave systems and subsequently became fascinated by the multi-disciplinary challenges of the materials, device, and circuit problem at hand. The FET was a new concept to microwave designers at the time, and I would like to show you the example that Charles used to explain its operation in those days. His first illustration, (due to his Swiss background) was based on mountains (see Fig. 5); but he soon learned that, on the West Coast, he needed a different approach, as shown in Fig. 6.

By 1971 his research team produced very impressive FET performance with low noise; high gain, and was subsequently awarded two Outstanding Paper Awards. Later, he also received the Microwave Prize with his co-author, Bob Tillman.

In addition to his work on devices, he was also interested in circuits, focusing on wideband, low-noise FET amplifiers. However, his interest soon expanded to include digital ICs. In 1974, together with Rory Van Tuyl, he disclosed the design and performance of the first GaAs logic gate. He also did some pioneering work on dual-gate GaAs FETs and became the National Lecturer in 1978.

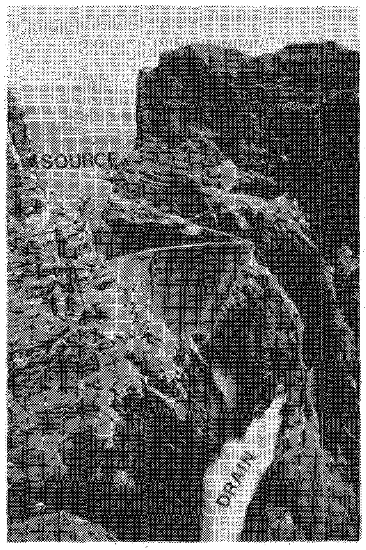

Fig. 5. Charles Liechti's initial concept of the GaAs FET operation.

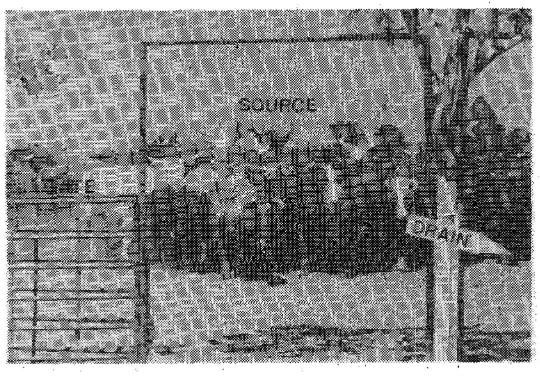

Fig. 6. Liechti's modified FET model for US West Coast audience.

According to a reliable source, the following incident took place during one of his lectures.

Charles, an extremely careful person, always required back-up equipment when giving a talk. Before presenting a lecture at UCLA, he inspected the back-up projector, back-up cord, and the rest of the back-up equipment. Finally, he proceeded with his talk explaining the operation of the dual-gate FET. Someone in the audience, who witnessed all the "pre-talk" preparations, stood up and asked Charles if the second gate in the FET was a "back-up gate".

By 1981, Liechti's team had produced a monolithic word generator operating at five gigabit per second data rate. Besides the usual design problems, additional difficulties had to be overcome: they had to develop complex packaging and testing capabilities to operate and measure the GaAs circuit at extremely high switching speeds.

I asked Charles to make a prediction about the future of microwave semiconductors. He points to the heterojunction bipolar transistors as an emerging bright star. He values the device as a superb power amplifier because of its large transconductance, uniform current density over the device cross-section, large breakdown voltage, low $1/f$ noise, and high frequency capability. In the near future, he expects to see heterojunction bipolar transistors with maximum frequency of oscillation over 300 GHz.

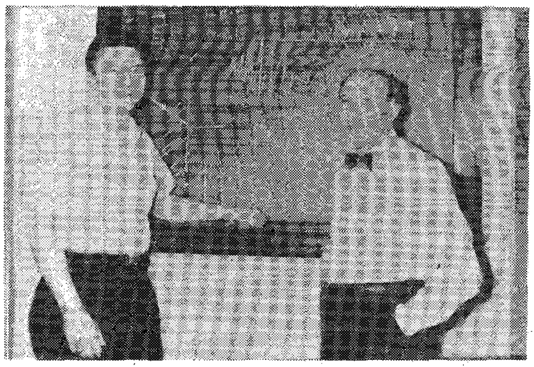
Fig. 7. Bob Pucel (left) with his MIT mentor, Prof. Guillemin.

Here we have a highly talented man who combined not only devices and circuit technology, but also analog and digital design.

The person I have chose to represent the 80' is Bob Pucel, a "generalist" who seems to know everything about everything. Bob has an incredible capacity for producing results in a short time. The following examples will help you appreciate this.

Bob's parents were poor immigrants who taught him early that hard work was necessary to succeed in life. He participated in sports and was a top student in high school. His interest in electronics also started at an early age by building phones from parts he scrounged from the local telephone company. He volunteered for the Navy in 1945 because of the extensive educational benefits. He received his BS and MS degrees from MIT in 1949 and 1951. Studied under Professor Ernest Guillemin, who was his mentor throughout later graduate programs. Bob accepted a position at Raytheon but told them from the beginning that he would only stay a year because he intended to get a Sc.D. Before re-entering MIT, he was married and within a short time, he and his wife had five children (remember, I told you that he could to things very quickly). Bob had the highest respect for Professor Guillemin (see Fig. 7) whom Bob described as an extremely challenging mentor whose greatest fear was that "perhaps one day computers will design circuits and the engineers will then stop thinking." (I wonder how he feels now about his "ace-student" eventually becoming an advocate of CAD?)

In 1955, after receiving his Sc.D., Bob accepted a job with Raytheon's Theoretical Physics Group where he got involved with bipolar transistors, although initially, as he stated, "did not know an electron from a hole." Within the next two years, his team invented a new type of high-frequency transistor, called a "Spacistor", which was expected to operate above 1 GHz. The Spacistor attracted the attention of several major publications such as Time Magazine and the New York Times, both publishing articles on the new invention. Bob also worked on negative resistance amplifiers and became interested in problems affecting transmission lines on high dielectric substrates. He did some original research with Daniel Masse on various types of transmission line phenomena, such as dispersion, loss of microstrip on dielectric and magnetic substrates. The results of their work laid the foundation for much of the later research in the same areas. His loss theory is the basic for all CAD algorithms.

Soon after, Bob had to make a decision whether he wished to become a manager or remain a technical contributor. After some soul searching, following a stint at management, he decided to stay in the technical field. Fortunately, he worked for a company where such a decision was acceptable, and he was able to continue as a highly respected engineering technologist. In 1977, Bob received a patent for the air-bridge crossover concept which was first used in power FETs and later became very popular in monolithic integrated circuits.

In the late 70', he began to work on FET mixers and oscillators, eventually designing circuits with conversion gain. Charles Liechti, editor of a special issue of the MTT TRANSACTIONS, persuaded Bob to write a paper describing his work on FET mixers (which Bob had no plans to do). Again, in a short time Bob produced a paper, and to his great surprise he, and his colleagues Dan Masse and Richard Bela, received the Microwave Prize for it.

In 1978, Raytheon entered the MMIC area and competed for a major contract to finance the development effort. Bob and his management team felt they would have a much better chance of winning the contract by demonstrating their newly established capabilities. Bob's manager asked him to design and build a working MMIC circuit within three weeks. Amazingly, without any background in CAD, Bob designed and *produced* a monolithic 1/2 watt power amplifier. He even learned how to use the COMPACT linear circuit optimization program; all within three weeks.

In 1979, Bob became the National Lecturer, and traveled throughout the world describing and promoting the monolithic microwave circuit approach. He still carries on this mission, having delivered over 80 lectures on the topic. He helped promote the field even further by being chosen as the editor of the IEEE reprint volume on MMICs a few years ago.

Bob always stated that a *truly* monolithic circuit had absolutely no interconnecting wires and the complete circuitry must be realized on a *single* chip. Then came a time when the really had to "eat his words." His talk, entitled "A Monolithic Transmit/Receive Module," was based on a product containing about ten different MMIC chips. Because of his own definition, he expected to be challenged, since he used the word "monolithic" in the title of his presentation. So, he invented the term "multi-chip monolithic" and to his delight, nobody questioned it (see what you can get away with when you already have a good reputation). Later the individual chips were integrated into a single chip. Fig. 8 shows his progress by comparing the relative sizes of the first monolithic circuit (the single-stage amplifier) and the complete transmit/receive module.

Bob is not your "typical engineer" by any means. He loves to talk, is very expressive, has great communication skills and is a good teacher being involved with continuing education at various levels. Bob represents that rare breed we need more of.

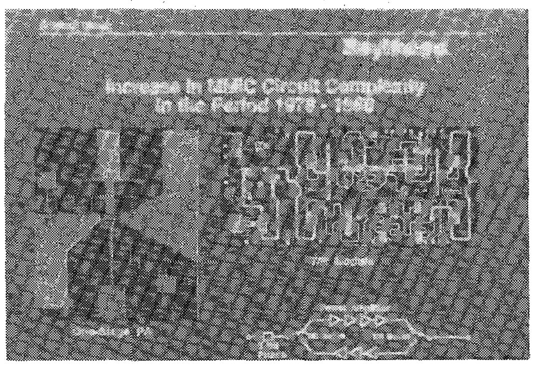

Fig. 8. Comparison of MMIC progress from 1978 to 1986.

Well, where do we go from here? Soon we will be in the twenty-first century. Information is being produced at a high rate by various means, transmitted from the land, sea and space. Eventually everything will depend on the little "black boxes" that will have to be designed and produced by someone. The question is: Will we have the right talent to design and build the systems of the next century? How are we going to attract, educate, train and keep our engineers happy and satisfied? Are we laying the right foundation to assure a successful future? If you have an opinion to express, please come by the panel discussion on Thursday noon and let us hear your views.

With these thoughts I leave you. Thank you for your attention. Enjoy the Symposium and good luck in the casinos.

**Les Besser** (S'64–M'66–SM75) was born in Budapest, Hungary, on August 27, 1936. He had completed technical high-school and escaped from the country following the 1956 revolution. He came to Canada and worked there for five years as a TV technician and a health-studio manager. Pursuing his lifetime interest in athletics, he entered college on a track scholarship, receiving a combined B.S. degree in electrical engineering and business administration from the University of Colorado in 1966. In that year, he was named as "The Outstanding Senior Student" and was placed in "*Who Is Who Among Students in American Colleges and Universities*". He also later received the M.S.E.E. degree from the University of Santa Clara, in 1973.

From 1966 to 1970 he worked for Hewlett Packard's Microwave Division, developing broad-band microwave components, receiving the patent for the first thin-film amplifier circuitry used in the CATV industry. He also had a strong interest in teaching and became involved with seminars on scattering parameter design and network analysis. In 1970 he joined the Microwave and Optoelectronics Group of Fairchild, concentrating on MIC's, GaAs FET amplifiers, and CATV systems and wrote the SPEEDY CAD program. From 1972 to 1976 he directed the microcircuit design and development effort at Farinon Electric Company.

During that time he wrote the basis of the COMPACT program for his thesis work at the University of Santa Clara and eventually converted the program to a commercial timeshare system. Bill Farinon, who himself was an entrepreneur, agreed to make the program available to outside users, and the foundations of the COMPACT business was formed.

Les soon realized that the involvement in his "side-interest" quickly exceeded the amount of his available energy and decided to dedicate full-time effort to microwave CAD. In 1976 he founded COMPACT Engineering to provide computer-aided assistance to the microwave industry through the COMPACT, AMPSYN, CADSYN, AND FILSYN programs. He also organized several successful continuing education courses to teach modern microwave circuit design at UCLA and other universities.

By 1980 the CAD/CAM interest was becoming significant and larger firms were entering into the market. Compact Engineering merged with COMSAT to form Comsat General Integrated Systems (CGIS). Les served as Senior VP until 1983, at which time he became a consultant to the company. His most recent involvement was the forming of Besser Associates, Inc., dedicated to short courses and video-taped continuing education.

Les has published over 50 technical papers and articles; was a contributor to "*Electronic Measurements and Instrumentation*", "*Computer Aided Design of Microwave Circuits*", and "*Microwave Transistor Amplifier Design*", co-author of "*Electronic Circuit Design Using Personal Computers*" textbooks. He is a Senior Member of the IEEE; was recipient of the IEEE MTT Microwave Applications Award in 1983 and the ARFTG Career Award in 1987, was past Chairman of the MTT as well as the Circuits and Systems Groups of the IEEE San Francisco Bay Area Chapters, organizing numerous short courses for their members. He served as Vice Chairman of the 1987 MTT Symposium in Las Vegas and of the 1971 Circuit Theory Symposium in San Francisco. He is also listed in "*Who Is Who In The West*" and "*Who Is Who In Technology*".