experiences with joy and wonder. I will always treasure those memories and experiences.

One of the things I most admired about Bernie was his endless curiosity. I think he genuinely loved learning about and understanding everything. He was an active listener, and you always knew he was truly interested in what you had to say. He loved to talk about everything from fly fishing to watchmaking, and he was always willing to share the wisdom of his experiences.

When Bernie and Bob Schiffman started the Microwave Working Group, it was to help others "bridge the gap, between technology and application". He was truly committed to helping others understand the benefits and limitations of Microwave and RF technology, accurately describing the advantages, without ever overselling the technology.

I always enjoyed talking to Bernie, and I will remember him as a gentle, friendly person, with an inquisitive soul.

Ed Ripley
President, Microwave Working Group

---

*After I forgot….lessons that I have learned**

Bernard Krieger
CEO Cober Electronics, Managing Director of CoberMuegge LLC, President of the Microwave Working Group

This article is the third in the series suggested by Ricky Metaxas for the benefit of the "new and younger fraternity of AMPERE". Ricky wrote the first entitled "Before I forget…" and Bob Schiffmann the second "After forty-two years, I'm still microwaving".

It is amazing to me how Ricky and Bob remember details about so many people and events. While Ricky entitled his article "Before I forget" I suppose mine should really be called "After I forgot" because my recollections about MW technology, I am embarrassed to say, go back more than the forty-two years documented by Bob. Scientists like Ricky and Bob probably have records of every paper they gave and every article they wrote. I have done a lot myself also, but I really can't remember those details because my focus has been to look at our industry as a businessman rather then as an academic. I measure my progress in dollars and in the number of friendships that I have made. The latter are very ample; the former, I can't comment on too much: but I can tell you that when I look at my company's financial statements sometimes the numbers look like Hippel's tables of dielectric loss factors.

Ricky and Bob recalled and mentioned almost all of the key names in the history of our technology. I too know most of them, but my approach is not to duplicate but rather to focus on the lessons that I have learned. I will pass a number of these on to you in this article as thoughts for the future, which will hopefully save you the expenditure of time that it took me to draw these conclusions. Since Ricky and Bob dated their first experience with MWs, I am glad to say I have been there longer! You of course can all also recognize me in the photo on page 2 with my first "MW processing system" in 1951. Most will recognize me: I look exactly the same today! In any case, I was operating a new MW radar system, which in those days had the remarkable feature to automatically control a 120mm aircraft gun. The "applicator" is depicted behind me in the photograph. To equate this to an industrial microwave processing system as used in a factory, there is in this process the production foreman whom I called " sergeant". He was a man of few words, in fact only one word, and "fire!" The machine operator who I call "corporal" was also of singular purpose because when he heard the foreman's utterance, his job was just to pull a

lanyard to start the process. Through-put was then quite rapid, about four thousand feet per second, and the entire process was accompanied with considerable noise and fumes.

This initial experience with an MW system was quite interesting. Similar to a home MW oven where the operator really doesn't know what's happening inside or whether the meal is hot enough until he tastes it, the concept of an automatic radar tracking system at that time seemed magical. Just in case the operator didn't believe that the gun was tracking precisely, the system had an optical telescope that followed the beam of the tracking radar. In any case, while training I turned on the MW generators, acquired an echo signal, and put the tracking system into automatic. I then looked through the telescope to see what had been acquired. Much to my surprise it was tracking a young nurse who was walking in the area. I had locked onto her zipper, which in those days was made out of brass and had a high reflection coefficient. I watched her in the cross hair that followed her with sort of a jerky motion. I was very young and didn't know much about zippers in those days so I shut down the radar, left the van and went to talk to her. As I approached to tell her what I had just experienced, she said that she felt quite warm, which immediately made me feel quite flattered. I thought it was my charm because at that time I didn't realize the effect of dipole rotation.

You would have thought that the 120mm gun tracking her would be alarming to her, but as I looked back at it, I saw that it was exactly opposite, 180° out of phase. Somehow, I had again reversed the polarity on the servo system (it was not a new experience for me). It was only two wires but it demonstrated to me a potentially dangerous personal fault and as it turned out, was one of the reasons that I later chose a career in business instead of engineering.

I founded Cober Electronics with my partner Sandy Jacobson in 1966, the same year that IMPI started. My initial business of course was military radar and countermeasures. The business had a good start because we opened by buying out a portion of Manson Laboratories which was the company that we were working for at the time. As a young MBA with a technical background I was sure that military markets were too cyclical and complicated and the potential for industrial microwaves in the future would be substantial. This was one of my first major market miscalculations knowing what I see of turmoil in the world today.

I joined IMPI in 1967 right after it started and I got to know - 2 - many of the young pioneers at that time that Bob has listed in his honour roll. I particularly admired John Gerling Sr. who had a knack for commercializing microwave technology into definable products. John was working for what was then the industrial microwave division of Litton Industries.

After a few years his company decided to leave off the industrial microwave business, much to my surprise, and John Gerling left the company. I saw that as excellent opportunity to join forces with John to really grow the industrial markets. In evaluating the merits of the potential relationship I decided to call a manager in the company to ask him about John and why they dropped out of the industrial microwave market. He explained that they felt that microwaves would develop as a substantial product for convenience in consumer home ovens and that market would be far greater than the industrial market. I couldn't believe what he said; who would ever think that microwaves would be in the home! Big business mistake number two for me!

The two mistakes mentioned above cause me to list for you:

Lesson number one: Focusing on your market can be much more important than focusing on your technology.

John and I never got together, we each were stuck in our own geography, he liked California and I liked Connecticut. We ended up with a fine relationship, but of the opposite polarity, we became competitors.

McDonnell Douglas (McDD), an aerospace Company also with a military background, saw potential for industrial microwave markets. Because of the space program McDD had a lot of capability in vacuum chambers to simulate outer space environments. They also had very strong system management capabilities. Why not use these to advantage? I met Fred Wear, the McDD scientist who was heading the project to develop microwave and vacuum technology for the drying

of grain on a massive scale for the US Department of Agriculture. Cober was the supplier of the microwave technology and McDD the vacuum and the overall system management.

The result after a couple of years of work was an outstanding machine that continuously fed grain into a microwave vacuum chamber and dried it at extremely high speeds. It was a pilot system. I remember the day at the US Department of Agriculture station in Georgia before a large audience when the machine was unveiled and demonstrated publicly for the first time. It worked perfectly. Fred and I were very happy because we had demonstrated feasibility. We were now ready to commercialize the process and supply equipment to dry billions of tons of grain produced annually in the US food belt. There was only one problem, the potential customers, grain drying companies and farmers, wanted to see pilot production on a larger scale than the lab system, which we demonstrated. Another machine was produced.

This system was three stories high with more than two hundred kilowatts of microwave power. I was not at the unveiling of that machine but the accountants were and while we reveled in the technical success, the accountants eventfully concluded that the capital cost for megawatt scale production equipment was not economical when compared to the drying capability of the sun plus gas fired hot air.

Grain was only worth a few pennies a kilogram. On the other hand, the active ingredients in drugs and pharmaceuticals can be worth fifty thousand dollars a kilogram: a big difference! The technology that was developed from the grain drier permitted McDD to help commercialize microwave vacuum drying of pharmaceuticals, a very active and productive technology today.

Lesson number two: Microwave technology & equipment are expensive. Use it to process high value materials.

We built a continuous pilot system for the cooking and rendering of meats and bacon for US Department of Agriculture.

My dear friend Bob Schiffmann assisted with the food technology and my company, Cober Electronics, made the system. During testing, we ate bacon off the production line until our stomachs ached and we came to the conclusion that with our microwave techniques we could get higher yields in cooking bacon. Great technology, but the food industry was selling precooked bacon to chains like McDonald's and others by the piece and not by the pound. It was not just a microwave machine like we had, but also a microwave machine and a high speed-slicing machine that mattered. Raytheon and others succeeded in that business because they took a broader view.

Lesson number three: Don't get hung up only on microwaves. Learn your customer's business: it's vitally important.

Several very brilliant scientists started Astex Corporation some years ago. They focused on MW plasma technology, chemical vapor deposition, making diamond coating with MWs, etc. To me their technology seemed unique and while they got involved in many different applications, some were also focused on the semi-conductor industry.

Diamonds sound exciting, but it was semi-conductors that were really growing because of the onset of the computer age. I saw that in a few years Astex then focused on the semi-conductor business and confined their activities almost totally to that area. The emphasis on microwaves became subordinate to a business concept that focused on semi-conductor processing machinery and Astex then grew very rapidly. They are now part of MKS Corporation, one of the world's largest suppliers of semi-conductor processing equipment.

Lesson number four: The word "microwaves" describes a technology not a business.

A business, on the other hand, is something that provides a tool or a service or a solution that is focused on the satisfaction of the customer's needs rather then only on a technology.

Learning the customer's business makes this more apparent. The answer to a heating problem could be infrared, hot air, steam, RF, microwaves, or combinations of these. The food machinery business, the semi-conductor machinery business, the rubber production machinery business, the ceramic industry machinery business, etc.- are real businesses, each requiring unique knowledge and experience. A competitor built a mobile high power MW system which was installed on a truck and had

an applicator focused on the asphalt pavement. The concept was that "amazing" MWs beamed into the roadbed, while the truck was travelling, would heat and reconditioned old and cracked asphalt. I thought, what a great idea! Our competitive response was to build an MW system that was installed on the front of a railroad locomotive with an applicator beaming down at the ice on frozen railroad tracks. We would melt the ice ahead of the train as the train moved. It would certainly save a lot of shovelling.

Lesson number five: Microwaves provide heat, not magic. Think of the practicality.
While I am at it, I should throw in a similar lesson, which is controversial but based on long experience.

Lesson number six: Non-thermal effects are wishful thinking and pie in the sky.
A kilowatt of MWs only heats materials that are receptive; whereas a kilowatt of hot air will heat anything.

My experience has involved me in countless applications based upon the principal benefit of MWs: high speed. Since the number of kilowatts that can be installed on the system relates to quantity and power of the microwave generators, speeds can be as high as the number of kilowatts on the system. The rule of thumb is that MWs are about five times faster than hot air. Unfortunately, we tend to think of speed in terms of the time it takes to process an individual part and not the overall time it takes to process the total daily production. To make an extreme example for the purpose of explanation, let us say that the conventional hot air process takes one hour while the microwave process can do the same part in one minute. However, the user with his conventional process can put sixty parts in a hot air oven at one time. The total production, therefore, of either the microwave system or the conventional system is exactly the same.

Lesson number seven: When using microwaves, think total productivity rather than individual part processing.

I think that the lessons from my experience are clear and can be summed up in one general overall message.

Lesson number eight: Bottom line is that economics can matter much more than the technology.
Customers care about money and cost on both short and long term bases. Ricky criticized me in the past for seeming pessimistic about our beloved technology, but that is not the case.

My objective is to be practical and extremely customer oriented. That is why I helped create the Microwave Working Group (MWG) that has been producing the World Congresses on microwave and RF processing. I am president of that group and we take particular pride in our mission, which is to Bridge Science, Technology and Applications. It is "the applications" focus that makes the Microwave Working Group unique. And it is a pleasure for me to work with the MWG team toward this customer oriented focus that our industry needs so very much.

I said in the beginning of this article that I will not focus on repeating names from the past, but I must say that some very fine engineers worked for me over the years. Without them and the many wonderful customers, we could not have installed so many new applications over the past 38 years. I specifically honor Wally Hickman, I. R. "Dick" Wayne, Dr. Charlie Buffler, Dr. Z. Y. Shen, Jerry White and Vern Magnuson. They kept the polarity straight for me. It is far better to keep your eyes on the target all the time so that the cannon won't be aimed backwards.

For further reading:

* AMPERE Newsletter Issue 42 October, 2004 https://www.ampereeurope.org/issue-42/