Engineering Education: Embracing Wireless and Moving Beyond

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The education of engineers with a specialization in the techniques required for high frequency design has not always been a straightforward process. In the past, a BSEE degree was followed by on-the-job training, both as formal training and less formal mentorship arrangements with more experienced staff. Later on, an engineer was usually supported with short courses and seminars to stay abreast of current technology, sometimes with tuition support for graduate study.

The process has changed for today's engineers. The biggest change is that the on-the-job training portion of this scenario has been eliminated at most companies. The investment in an individual engineer's career through education is less important to a company—and is no longer supported by the government/military dominance of the industry that was present from World War II to about 1990. Instead, incentives (mainly stock options) are used to encourage engineers to stay with a company and contribute to its success.

Without a good follow-up to a BSEE, some companies began demanding that colleges and universities provide more industry-specific training in the undergraduate program. Whether or not this is the right approach has been hotly debated over the past decade, but that debate has begun to abate as the right balance is found. That balance between general education and specialized training has been accomplished in several ways, which will be the major part of this report.

The Master's Degree as Specific Training

The most traditional method for adding technology-specific education to a BSEE is further study, usually a course of study and research leading to an MSEE. In the areas of high frequency technology—RF, microwave, wireless and high speed digital—this method is growing along with the industry. Students seeking successful careers in an increasingly entrepreneurial job market are continuing study past a BSEE and exploring various areas in greater depth before seeking employment. In a few cases, companies will support students whose research focus is aligned with their needs.

Areas of current graduate-level research include the expected "hot topics" of wireless systems: network theory and network management, propagation for developing applications like WiMAX and ultra wideband (UWB), sensors and sensor networks, plus technology enhancements like MIMO and reconfigurable digital radios.

Research at a more microscopic level may emphasize components through materials research and new semiconductor process developments. Nanotechnology is a new area of attention, with high frequency applications in switches and resonators being the most-often mentioned research subjects.

Beyond these "headline" subjects are more mundane, but eminently useful, research topics. Many are focused on refinements in technology—making the next small step rather than working on something with applications that are further into the future. For example, in the late 1980s, while high temperature superconductivity was getting all the press coverage, exceptional research was quietly being pursued in electromagnetics modeling, large-scale RF integration and propagation in difficult environments. The results of these latter efforts have had a much greater effect on real-world applications than more highly-publicized subjects.

A few of these evolutionary research topics include further refinements in electromagnetic modeling to accommodate practical needs at mm-wave frequencies and in large-scale problems. Also being studied are detailed analyses of individual portions of larger topics—noise in low voltage and low power ICs; more com-

pact topologies for filters, couplers and antennas; case studies of propagation in urban environments; code development for digital predistortion; and many others.

As the above summary shows, a large amount of work is being done in graduate research to support specific needs of industry. The students doing this work will then have the inside track for jobs that implement their research results in practical products. This process has been occurring for many years, and there are no signs that this part of engineering education will change any time soon.

High Frequency-Aware Curricula

Another method for developing engineers specifically for the high frequency industry has been implemented at a number of schools around the country. These engineering departments have added or modified courses within the normal EE program to raise students' awareness of issues involving RF, microwave and wireless technologies.

In some cases, new course sequences have been developed, in much the same way as was done for digital circuits and microprocessors in the 1970s. In my opinion (and that of many experienced engineers), the best of these new course offerings include hands-on lab work that mimics the real-world work environment. The projects may be "generic" to maintain a consistent technical level, but the process is really independent of the specific circuit—design by selection of circuit topology and components, modeling and simulation, breadboard construction, test and measurement ... and the repeat of this process for optimization.

Most engineering departments now offer courses to support RF/microwave/wireless technology. The variations in the focus of these courses are significant and prospective students must evaluate them carefully to determine how they fit with career plans. For example, courses that appear nearly identical in title and description may have completely different emphasis—one may be circuit-level oriented (hardware), another may be high-level system oriented (data stream/software), while yet another may be a broad survey of technology with little depth in either area.

The Impact of Individual Instructors

Another well-established method for developing students with high awareness and capabilities in a given emphasis area is the mentorship of one or two professors in an engineering department. A comment regularly heard within industry engineering staff goes something like, "We hire a lot of students who studied under Dr. *xxx* at nearby *yyy* university."

The proven success of students prepared by a knowledgeable instructor provides an excellent pathway from school to job. Often, an employer in the area is a heavy recruiter, which gives many EE graduates their first job without a lot of job-searching anguish. Whether these new employees stay or move on is another matter, but getting that first job is a significant hurdle for a large number of new graduates.

Why the Debate is Slowing

The debate of the recent past over "specific training versus solid fundamentals" is not gone, but is fading rapidly. I think this is due to two related factors: the wireless industry is substantial and mature, and new technologies are getting the headlines.

The maturity of a technology into a mainstream application area means that it will be supported to some degree by all engineering schools, and will be a major area of emphasis at a significant number. The level of educational support for industry has increased to the point where it appears to be sufficient for present needs, and those of the near future.

The rise of "newsworthy" technologies such as nanotechnology and bio-electronics has replaced some of the hoopla over the wireless boom. The boom is far from over, but it is no longer a "future" technology. Internal political pressures within universities change accordingly, and no longer add fuel to the debate over how to accommodate industry's needs.

In short, high frequency technology in the university environment has (for the most part) gained a spot among the core subjects, following the historical path of power distribution, radio (the original wireless), solid state devices, digital electronics and microprocessors.

Continuing Education

The issue of maintaining competence through formal instruction is less well-established. The traditional methods used by large aerospace companies prior to 1990 are now used only by a small number of companies. Internal seminars and conferences have all but disappeared, and support of advanced study has been greatly reduced.

As a result, the individual bears far more of the burden for advancing his or her knowledge through college courses, short courses and conferences. But there is some evidence that the trend is reversing.

Demand for short courses, while still reduced, is very broad-based. The growth in wireless technology has greatly broadened the number of applications that must be understood by engineers and management alike. The difficulty of this trend is that the number of subjects to be covered has become immense—ranging from CMOS RFICs to the economics of value-added services overlaid on a wireless network. This part of engineering education will present the greatest challenge over the next several years.