AC 2012-5273: DEVELOPMENT OF A DYNAMIC CURRICULUM FOR WIRELESS COMMUNICATIONS: ADDRESSING THE REQUIRED WORK-FORCE FOR WIRELESS INDUSTRY AND ACADEMIA

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Development of a Dynamic Curriculum for Wireless Communications: Addressing the Required Workforce for Wireless Industry and Academia

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Abstract **–** There are emerging applications for wireless communication systems. New technologies are developed in this field in a rapid pace, and industry is in an increasing need of well trained and skilled graduates. They need these graduates to get integrated with their already existing employees without any further training or with minimal training.

However, in general, currently, students graduated from universities and colleges are not trained properly and/or do not have enough hands on experience to address the increasing need of industry in many fields of Wireless Communications. In addition, there is not a proper tie between wireless industries and academia. In general, there is a feeling in the industry that students do not attain the desired experience and skills. It is desired that students receive hands of experience on Radio and its design and concepts such as Synchronization, OFDM and standards. In addition, there exists a considerable lack of training and hands-on-experience on working with advanced instruments (e.g., spectrum analyzer, and network analyzer), programming devices such as DSP and FPGA, and designing and implementing digital signal processing methods, and Radio RF components such as Antenna, LNA, Mixer and RF Filters.

This paper investigates the contents and the dynamics of a set of curriculum for Wireless Communications. A survey that is distributed across multiple industries in Wireless Communication is analyzed to determine (a) the general topics (curriculum subsets) that should be covered to create a complete curriculum in Wireless Communications, (b) specific information that should be transferred in each general topic (curriculum subset), and (c) topics important for developing hands on experience and improving students skills (such as lab and enterprise experiences).

1. Introduction

Wireless communications has many existing and emerging applications in today's life. Every day, new applications for wireless communications are emerging. Examples include handheld mobile devices, wireless indoor and outdoor localization systems, and 911 and emergency services [1]. A new application is space-based power transfer which requires knowledge of microwave circuits and devices, antennas, and high power radios [2],[3]. Another example is cognitive and software defined radio that increases the dynamics and the functionality and enables radios to work in different environments and adapt with a variety of transmission standards, and efficiently use the available spectrum [4], [5].

Based on Cisco reports, 62 percent of all Americans are part of a wireless, mobile population that participates in digital activities and that Global enterprises will spend US$4.6B on Web 2.0 technologies by 2013. iQmetrix, which provides retail management software for the North

American wireless industry, recently released the results of its survey on “State of Wireless Industry”. Results of the survey reveal that, despite economic uncertainty, 70% of the polled 158 independent wireless resellers in North America expected the wireless industry to grow in the next five years, and nearly 50% of the mobile resellers foresee recruiting and retaining well-trained staff to be one of their biggest challenges. AT&T promises to expand 4G LTE deployment to 95 percent of the US population – urban and rural areas. AT&T’s mobile data traffic grew 8,000 percent over the past four years and by 2015 it is expected to be eight to 10 times what it was in 2010.

The above points confirm that the US wireless industry has an increasing need for skilled college graduates who are well-trained and who have hands-on experience on how a radio is designed and programmed and how microwave circuits and devices and antennas are developed [6]-[8].

Today, however, the curriculum of Electrical Engineering (EE) departments in the field of wireless is deficient in two general aspects: (1) many courses such as communication circuits, microwave devices, antennas systems and transmission lines are either traditionally offered or they are fully eliminated from the curricula; hence, students are minimally exposed to these important topics or do not receive hands-on experience in these area. Thus, students are not exposed to a broad and in-depth training; accordingly, industry must allocate valuable resources to training programs for new graduates. This consumes a good portion of industrial resources; (2) there is minimal training program that equips EE students with leadership and entrepreneurship experiences and enables them to create startups and jobs in the wireless industry.

Wireless communication systems and their applications shape the future; hence, it is critical to prepare the US workforce for emerging wireless applications and industries and to avoid wasting valuable industrial resources to train graduates when our universities can and should be performing this function. It is essential to create jobs for the future of this country and it is crucial to build a young generation of students to be great leaders, innovators, and entrepreneurs in the wireless industry, to be, the Steve Jobs of the coming decades.

This paper conducts a preliminary survey which confirms that the current practice in many universities for teaching the materials needed for the field of wireless communications is not consistent with industrial requirements. The approach toward the development of a new curriculum is explained, which will include hands-on experiment designed based on the immediate wireless communication industrial needs and offered in new and transformative ways.

2. The Survey

A survey was created and conducted on the industry professional. The survey studies two aspects of the proposed new curriculum: (a) the scientific or theoretical skills, and (b) hands-on experience skills. The questions of scientific and theoretical skills are listed in Table 1. Hands-on experience questions ask whether: (i) experience of measurement devices is needed; (ii) hardware skills should be improved via specific approaches; and (iii) experience with some software should be included. Table 2 summarizes topics in each item (i)-(iii).

The survey had six possible answers for each item in Table 1: (1) “not at all”, (2) “concept”, (3) “Theory”, (4) “Theory and Project”, (5) “Theory and Problem Solving, and (6) “Theory, Problem Solving and Project”. Respondents could select “I don’t know” if they do not know the topic. “Concept” means the topic is slightly important and a short reference to the topic in the curriculum suffices. “Theory” means extensive introductions are needed. Respondents could also choose “Problem Solving” and “Project” if they feel these are critical in addition to theory. In summary, the questionnaire used a categorical measurement scale with 6 nominal levels for each item, as depicted in Figure 3.

Each question presented in Table 2 could be answered by “Strongly Disagree”, “Disagree”, “Slightly Disagree”, “Neither Disagree nor Agree:, “Slightly Agree”, “Agree”, and up to “Strongly Agree”. This could also be mapped into different levels of required class or lab coverage that could go from no coverage up to detailed coverage consistent with Figure 3.

The questionnaire includes the demographic info of the companies. Different categories of companies include those involved in microwave component design, RF component and Antenna design, networking or sales only, etc. It is expected that unlike companies answer the questions differently. Thus, the coverage curve of Figure 3 could vary across different companies. It should be noted that currently, the topics shown in Table 1 are discussed in the courses such as Wireless Comm., Comm. Circuits, Digital Comm., Antenna Systems and Microwave Devices. However, the purpose of our research is to create a concentration for undergrad students that would include only three courses.

Thus, it is critical that ultimately the overall curriculum is designed optimally within three courses and their associated labs as shown in Figure 1.

Table 1: Survey materials: Theoretical and Scientific Skills.

Theoretical/Scientific Skills
1. Analog Modulation Techniques / Circuits / Performance Analysis;
2. Random Process and Applications;
3. Sampling and Quantization Theory;
4. Information Theory;
5. Digital Modulation Methods (QAM, PSK, FSK, ASK);
6. Other Digital Modulation Methods (specify);
7. Optimum RCVR Design / Performance Evaluation;
8. Phase and Frequency Synchronization/Channel Estimation/Equalization Techniques;
9. Communication Standards;
10. Channel Coding Schemes;
11. Optimum Diversity Receivers;
12. Channel Modeling (Large and Small scale) and Wave Propagation;
13. Comm. Technologies/Standards (WiMAX, LTE, Cognitive Radio, Software Radio, etc.);
14. Multiple Access Theory;
15. Multi-carrier Transmission (MC-CDMA/OFDM)
16. MIMO Systems;
17. Smart Antennas/Beamforming Methods;
18. Time-of-Arrival / Direction-of-Arrival (DOA) Estimation;
19. Cognitive/Software Defined Radios;
20. Transmitter Design;
21. Detection and Estimation;
22. Receiver Design (Sensitivity, Dynamic Range, Noise Figure);
23. RF Component Design Including Low Noise Amplifier (LNA) Design, Mixer Design, Pass band Filter Design;
24. Noise in Communication systems;
25. Pulse Shaping and its Impact on Performance;
26. Channel Estimation/Phase Frequency; Synchronization Techniques;
27. DAC and ADC adjustment and Digital Down Converter (DDC) design;
28. Multi-Channel/Antenna Calibration for Beamforming and DOA Estimation;
29. Clock Pulse generator design;
30. DSP and FPGA Programming;
31. Antenna Parameters (pattern, gain, return loss, beamwidth, bandwidth, etc.);
32. Antenna / EMAG Theoretical Principles;
33. Antenna Design for Mobile Devices;
34. Antenna Testing (e.g., in Anechoic Chamber);
35. Mutual Coupling in Antenna Design;
36. Impedance Matching;
37. S-Parameters and VSWR;
38. Microwave Measurement Devices;
39. Microwave devices in 60GHz, and Terahertz;
40. Waveguide principles and design;
41. Impedance Matching for Microwave devices;
42. Microwave devices (TWT, directional couplers, Circulator, Magnetron and Klystron, Solid State Amplifiers, Phase Shifters, Attenuators);
43. Other Microwave Devices (specify);
44. Other Topics (specify);

Here, the number of courses selected in the concentration is three because usually in many universities a concentration is preferred to include 12 credits. Three three-credit courses and their associated labs (each one credit) form a 12 credit concentration.

Table 2: Hand-on Experience Skills questionnaire.

(i)Measurement Devices	(ii) Hardware Experience should be conducted via	(iii) Experience with Following Software needed
A. Spectrum Analyzer	A. Software only (simulink, labview, etc.)	A. ANSOFT/HFSS
B. Network Analyzer	B. Programmable Radios (e.g. USRP)	B. LABVIEW
C. Vector Analyzer	C. Real Radios (modems, IEEE 802.11, etc)	C. MATLAB
D. Vector Signal Generator	D. Software and programmable radios	D. C++
E. Digital Analyzer	E. Software and real radios	E. JAVA
F. Others (specify)	F. Others (specify)	F. Others (specify)

3. Survey Analysis

The analysis results are depicted in Figures 1 and 2. Figure 1 represents the response that received the maximum percentage in the survey. The results confirm that many topics such as Optimum (including diversity) RCVR Design / Performance Evaluation; Phase and Frequency Synchronization/Channel, Transmitter Design and RF component design, and Digital Modulation Methods should include theory, and practice. Today many of these topics are taught in concept only and some such as RF design is not covered at all. In addition, the results show that some topics such as Antenna testing, microwave measurement devices, impedance matching, and Microwave devices should include problem solving as well as theory and practice.

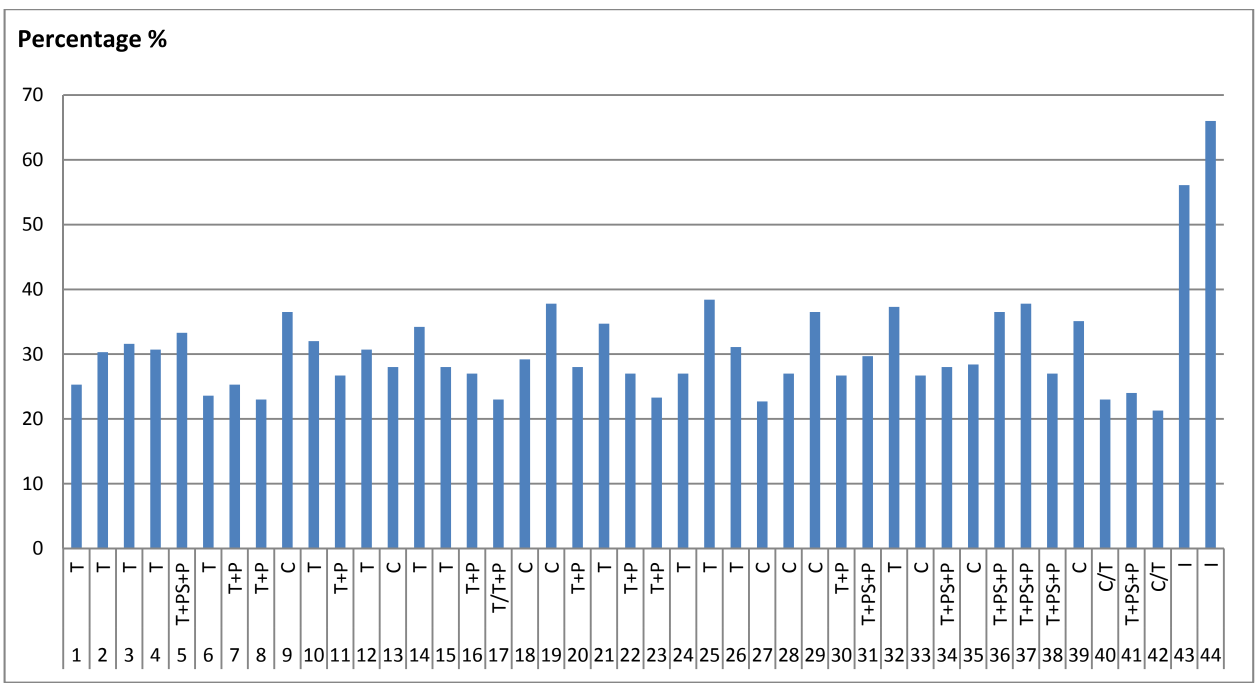
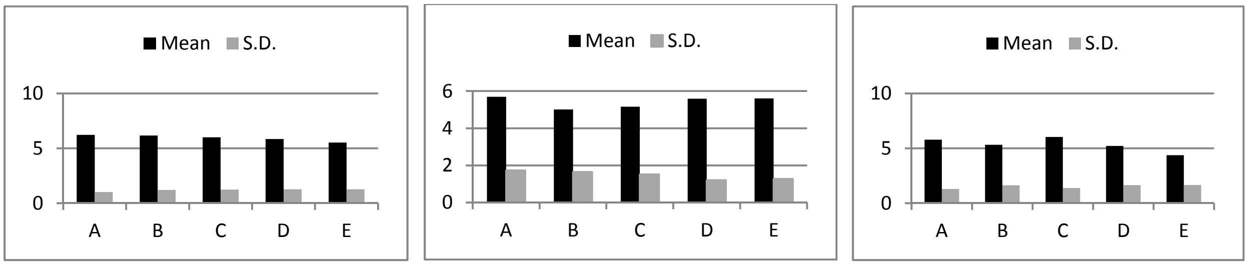


Figure 1: Survey results for Table 1; here, I=I don't know, C=Concept, T=Theory, P=Project, PS=Problem solving.



(i) Measurement Devices (ii) Hardware Experience (iii) Software Experience

Figure 2: The survey results for Table 2.

Currently, many universities have removed these topics from their curriculum and minimally teach microwave and antenna courses. The survey outcomes confirm that many of the mentioned topics are not consistent with the current practice in the majority of universities and colleges in the U.S. Indeed, currently, there is barely any well-established curriculum that covers topics such as transmitter and receiver design and RF design.

In Figure 2 the Y axis is formed by allocating weights that start from 1 to "Strongly Disagree", to 7 to "Strongly Agree". The results of our survey from industry strongly suggest that students should gain a solid hands-on experience on all measurement devices, hardware and software presented in Table 2. Only Java received a low scoring compared to other topics. Therefore, it is critical that the curriculum to be designed to add laboratory components to help students gain hands-on experience with the hardware and software listed in Table 2. As part of this proposal we plan to develop a proper curriculum for these topics and cover them within at most a three course communication curriculum as detailed in Section 2.

The results of Figures 1 and 2 confirm that the current practice of teaching Communication courses such as Wireless Communications, Communication Theory, and Digital Communications are not fully consistent with the needs of industry. In addition, it is clear that many components of Communication Circuits and Antenna and Microwave Theory should be injected to the current curriculum. As explained in the next section, we plan to form a concentration in Wireless Communications that will be consist of three courses (preferably) and their associate lab.

4. Curriculum Adjustment Approach

The process of curriculum adjustment has been explained in Figure 1 and consists of the following steps:

(1) Conducting a comprehensive survey of the required topics with industry. As shown in Figure 1, industrial focus groups are surveyed to create the first draft of the curriculum plan; the survey will focus on the knowledge and skills (including problem solving skills) that are specifically required for students to have in order to tackle real industrial problems;

(2) Based on the survey results, a new three-course undergraduate curriculum that transfers key wireless system design information and studies emerging topics in wireless industry and communications will be developed. Based on the current curriculum standards and practice of colleges, three courses along with their laboratories (total of 12 credits) can define a curriculum concentration. The courses will be designed to optimally include all topics suggested by the survey. It will also contain application-based examples with the goal of

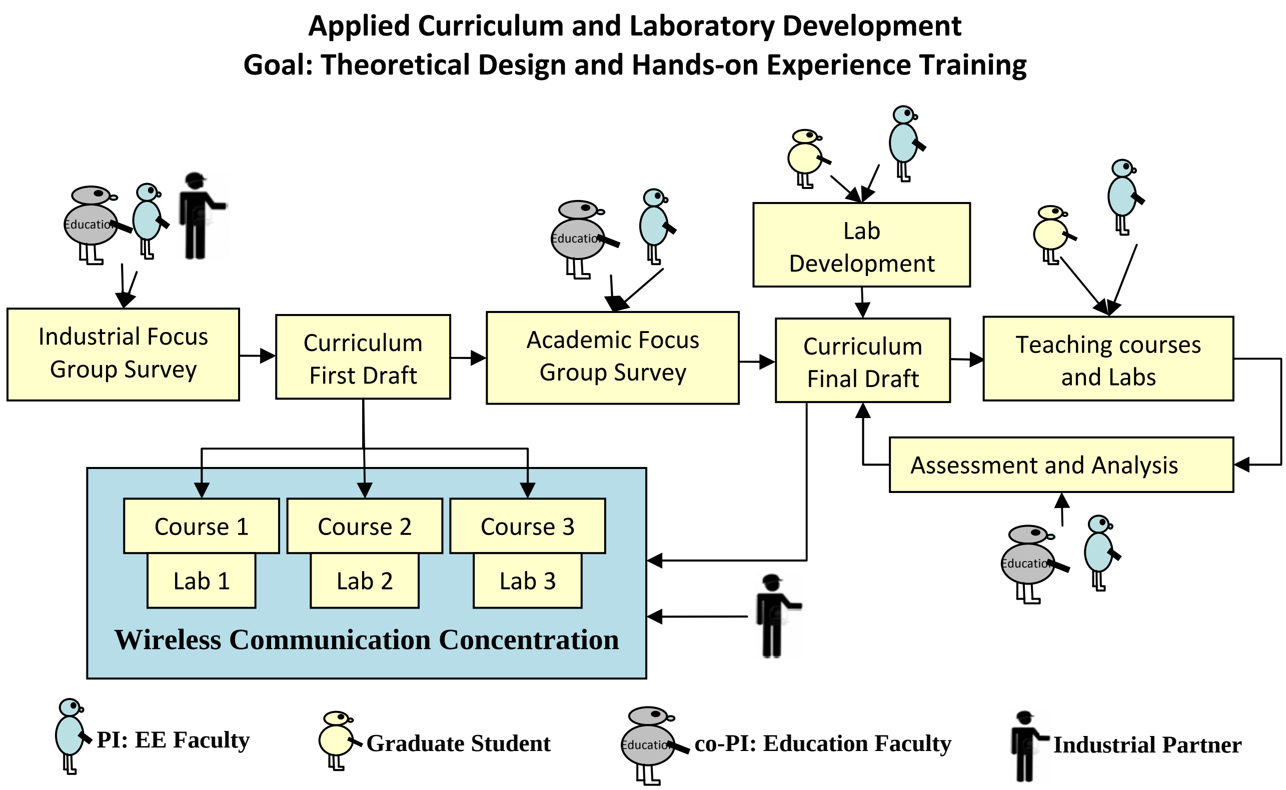


Figure 1: A sketch of the first goal of the proposal and contributors in each part.

bringing real world problems from industry into the classroom. The laboratories will complement coursework with relevant and challenging hands-on experience;

(3) The developed curriculum will be finalized by surveying college educators who teach related courses;

(4) In parallel, the required labs that are also well tuned through focus group surveys are designed with the support of graduate and undergraduate students as well as our industrial partners.

5. Conclusions

A preliminary study and survey was conducted to highlight issues with the current practice in teaching wireless communication courses. It was depicted that many courses and hands on experience required by the industry is not included in the current communication theory curriculum. Therefore, it is suggested that the curriculum is revised to support the current and futuristic needs of industry. A method for approaching to the curriculum revision process was proposed.

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Wireless carriers have already started to advertise around it, and tech prognosticators have begun offering visions â€” terrifying, revolutionary and everything in between â€” about the kind of future that 5G wireless networks will deliver. But who's going to build and maintain those networks?Â But traditional cell towers will still be a key part of the infrastructure, and industry estimates suggest that there are 20,000 jobs waiting for tower climbers.Â Other legislative proposals include a measure to require the Federal Communications Commission to empanel an advisory council to help it craft policies to promote workforce development. A labor shortage, the nominal subject of Wednesday's hearing, is just one component of the bigger challenge around the digital divide. IO-Link wireless addresses reservations about using wireless technologies. Despite all of the benefits that wireless connections have on the field level, there are some reservations; radio links feel less reliable. What about interference from other machines or other wireless communications?Â requirements factory automation demands from a wireless communication standard in terms of robustness and performance. With TIâ€™s pre-certified module CC2650MODA and Kunbusâ€™ development toolkits reliable, industrial equipment based on IO-Link wireless can already be created. ResourcesÂ TI grants you permission to use these resources only for development of an application that uses the TI products described in the resource. Other reproduction and display of these resources is prohibited. Wireless operators have worked hard to accommodate the increased demand for data services over wireless networks. They have been forced to consider alternative offload strategies, including wirelessly connecting electronic devices (Wi-Fi). Unfortunately, the majority of smartphones being introduced into the marketplace only support Wi-Fi at 2.4 Gigahertz (GHz), which is rapidly increasing pressure on Wi-Fi designers and administrators to design products for the smallest segment of bandwidth available.Â It would result in the same coverage area of a single cell and likely would not cover the required area, even in a relatively small lecture hall. Data rates are a function of the received signal strength and the signal to noise ratio (SNR) at the receiver. The author develops systematic methods for RF systems design, complete with a comprehensive set of design formulas. Its focus on mobile station transmitter and receiver system design also applies to transceiver design of other wireless systems such as WLAN. This comprehensive reference work covers a wide range of topics from general principles of communication theory, as it applies to digital radio designs to specific examples on implementing multimode mobile systems.Â RF System Design of Transceivers for Wireless Communications. @inproceedings{Gu2005RFSD, title={RF System Design of Transceivers for Wireless Communications}, author={Q. Gu}, year={2005} }. Q. Gu. Published 2005. Engineering. Xiaoyang Liu, Chao Liu, "Wireless Sensor Network Dynamic Mathematics Modeling and Node Localization", Wireless Communications and Mobile Computing, vol. 2018, Article ID 1082398, 8 pages, 2018. https://doi.org/10.1155/2018/1082398. Show citation. Wireless Sensor Network Dynamic Mathematics Modeling and Node Localization.Â With the rapid development of wireless sensor network (WSN) technology and its localization method, localization is one of the basic services for data collection in WSN. The localization accuracy often depends on the accuracy of distance estimation. Because of the constraint in size, power, and cost of sensor nodes, the investigation of efficient location algorithms which satisfy the basic accuracy requirement for WSN meets new challenges.