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Education, Experience, and Certification Through Micro-Credential Program in RF Engineering for Engineering Technology Students

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Work in Progress: Education, Experience, and Certification Through Micro-Credential Program in Radio Frequency Engineering for Engineering Technology Students

Introduction

Radio Frequency (RF) Engineering is a field in electrical engineering that studies the properties and applications of signals in various frequency ranges from tens of hertz (Hz) to a few hundred gigahertz (1 GHz is 10^9 Hz). The main subjects in RF engineering include topics such as antennas, transmission lines, signal propagation, and components used in RF systems.
The demand for RF engineers has been increasing recently due to the proliferation of wireless devices and applications in both commercial and defense settings. There is a shortage of both new and experienced engineers in RF engineering. The complete RF engineering curriculums are not generally offered at the undergraduate level. As providers of engineering technology education, when designing a new course or a program, we must consider the applicability and practicality of the course contents and the program. A micro-credential is a certificate program that helps students acquire knowledge, skills, and experience in a highly focused area by completing three or four relevant courses. The micro-credential in RF engineering for students in engineering technology programs must also be designed and implemented in such ways that the courses in the micro-credential are as self-contained as possible so that it does not put additional coursework burden on the students with prerequisites not required by the degree programs. This also can create a higher level of interest from part-time students and students in professional development. The courses described in this paper are constructed with a bottom-up approach. This approach takes priority in learning hands-on skills such as competency in utilizing equipment for RF testing and measurements. Lessons on making the physical interpretation of the testing and measurements are given only after acquiring the proper hands-on competency levels. This approach contrasts with the traditional engineering technology courses with lab components, where students learn the theoretical foundations first and verify the theories through the lab activities. This paper provides details on how the micro-credential in RF engineering can be established with the courses tailored for students in engineering technology with the bottom-up approach. In addition, the faculty has pursued and received collaboration from the local RF engineering industry to ensure the students acquire the skills that are considered essential and would give a competitive advantage in employment opportunities to the students with the micro-credential. The feedback and assessment results from the first course in the micro-credential were overwhelmingly positive. The enrollment in the upcoming semester is expected to be doubled from the last time the class was run based on early enrollment numbers and the heightened interest level during pre-enrollment advisement. The micro-credential program described in this paper not only provides a detailed coursework setup in RF engineering technology but also integrates real-world experience through applied learning such as internships, co-op programs, or senior capstone projects.

Micro-Credential Program - Overview

According to the State University of New York (SUNY), a micro-credential is a valid learning experience with learning outcomes, assessments, and examples of student work [2]. The program with a micro-credential will not only attract a higher level of interest from the students but also reward the students in the form of a competitive edge in the job market for completing the curriculum. According to the study by the UPCEA (University Professional and Continuing Education Association), 95% of 500 surveyed recognized benefits from micro-credentials because they show employees' willingness to develop skills and are an easy way to communicate skills and competencies [3]. In 2018, 525 micro-credential programs were established in more than 60 different disciplines. 75 micro-credentials result in industry certifications while 215 micro-credentials are licensure-related [4]. Many universities and colleges across the nation offer micro-credentials or similar programs such as *University Learning Store* involving six different universities in collaboration, *Degree Plus Certificates* at the University of Utah, and *MBlem* at the University of Michigan.

The micro-credential can be an attractive goal for potential part-time students when the RF curriculum is a track in a professional development program for even wider participation in the RF micro-credential. Micro-credential program is not a complete track in a major. Thus, it is easier to implement a micro-credential program in an engineering technology curriculum with one of the learning outcomes being proficiency in practical skills used in the industry. For this, RF engineering micro-credential is an ideal area in electrical engineering technology to implement the micro-credential. The micro-credential in RF engineering can be designed to meet specific qualifications demanded by RF engineering industry.

Micro-Credential – Industry collaboration

One of the key components of micro-credential in RF engineering is collaboration with RF industry. The major goal of micro-credential in RF engineering is to provide a competitive edge in the job market. The competitive edge comes from the specific technical skills the engineering technology students acquire from the micro-credential program. Those technical skills in the micro-credential should be recognized by the industry. It is extremely critical that an effort to take input from potential employers of our students in all stages of micro-credential implementation such as the coursework design, student learning outcomes, and the assessments. A formal recognition or even a simple understanding of the micro-credential as a skillset certification by the companies will boost the value of the micro-credential in RF engineering. This can easily broaden internship opportunities with companies for our students. In turn, the program can receive more direct feedback on the micro-credential in terms of what is needed to improve the program to better meet the company's needs. Thus, the micro-credential program should be implemented with a continuous improvement cycle with periodic discussions with the industry. It would be beneficial to have representatives from the RF industry on the advisory committee for the program department.

Education - Approach

In general, an RF engineering track at the undergraduate level requires four or more courses specific to RF engineering. Figure 1 illustrates a general flow of the course sequences employed in a typical RF engineering curriculum. It would be a very difficult task to integrate these RF engineering courses into the degree program without making changes to the general curriculum.

These additional courses would put engineering technology programs under a heavy burden to implement the changes as their programs have limited flexibility under the baccalaureate degree and ABET requirements. Engineering technology programs rarely have different tracks available within the major due to the limitations on instructional resources. These courses also put students in the engineering technology programs in uncomfortable places as most of the courses' contents are highly theoretical. The utmost goal of engineering technology programs is to prepare the students with practical skills that are directly applicable to the industry. With this goal in mind, a seamless integration of the RF courses into the program curriculum should be devised. One of the ways to implement the necessary courses seamlessly is to use technical electives allowed in the program curriculum to teach the necessary RF engineering courses. This approach minimizes the impact of creating the RF engineering program on the existing curriculum.

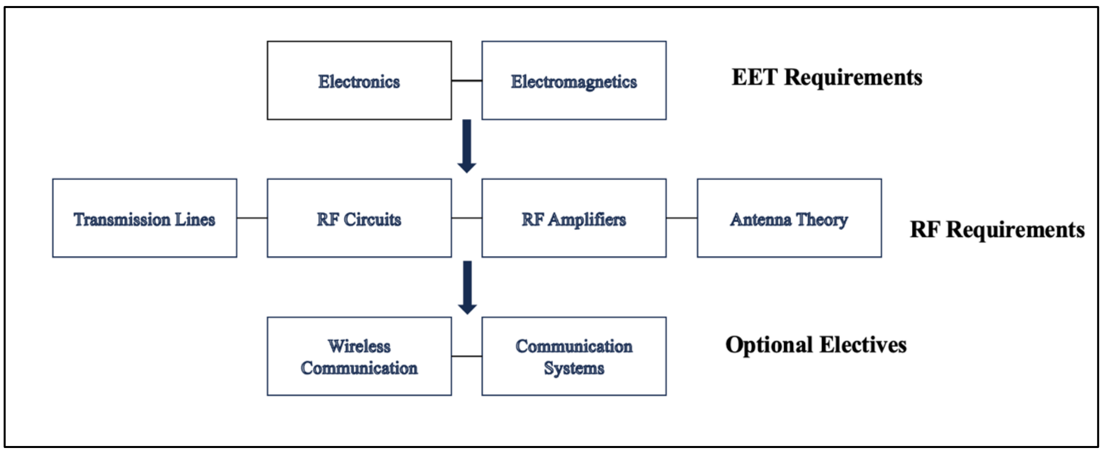

Figure 1: RF Curriculum Overview

Even with RF engineering courses as technical electives, it would not be easily feasible to add all the traditional RF engineering courses to the degree programs due to the restriction on the maximum number of credits for a degree. The RF program proposed in this paper requires three courses, two of which are technical electives, and the third course is the senior capstone course. These courses are usually already included in the existing curriculum. Thus, no extra coursework is required for the RF program. It is critical to include all the essential skills and techniques in RF engineering in two courses the student would take in their third year. Having all the essential RF topics covered in two courses is not only impractical but also ineffective with the traditional approach of theory-first and verification of the theory in the lab. A different pedagogical method is necessary. In engineering technology programs, more emphasis is put on practical knowledge of the topics rather than theoretical analysis of the topics. An opposite to the traditional teaching method can be used for this program. That is, start with an introduction to major equipment used in the RF industry and the measurements they can perform. Each measurement can now be taught in terms of what it is and how it should physically be interpreted. This practical lab-first and theory-second approach can not only be more effective but also desirable for our engineering technology students as it lessens the dependency on prerequisites in mathematics and physics. In Figure 2, an example of the instructional flow for Voltage Standing Wave Ratio (VSWR) with the practical approach is compared with the traditional instruction flow. The proposed instructional flow with a higher priority on practical skills desired by the industry suits the needs of engineering technology students better by providing measurement techniques and the ability to physically interpret the data. This approach can shorten the amount of time needed to deliver practical knowledge on the topics covered in the courses.

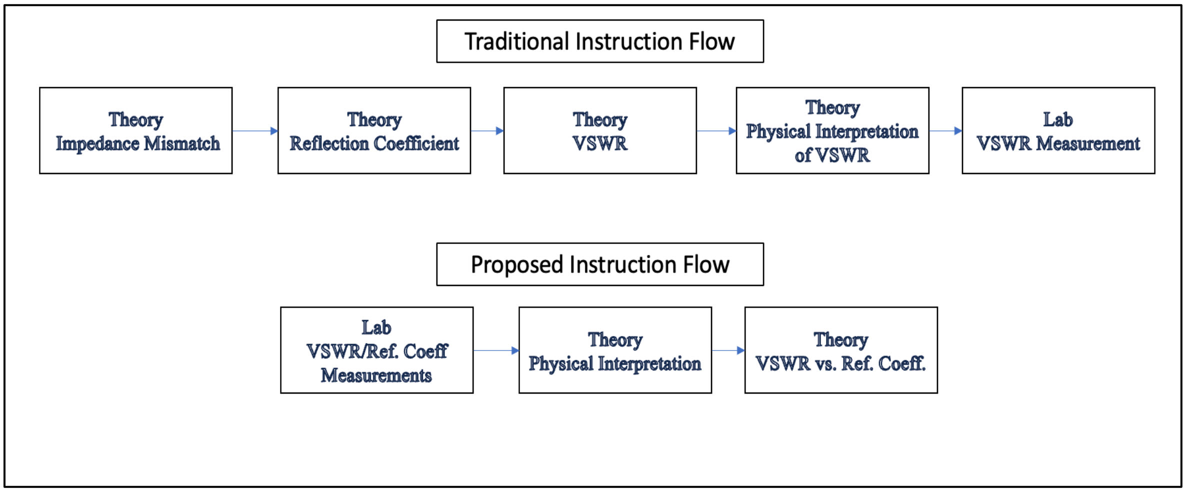

Figure 2: Instructional Flow Comparison

Education – Courses and Student Learning Outcomes

The first two courses in the proposed RF program are taken as technical electives. The topics covered in the courses are categorized based on the RF-related measurements that can be made by major test equipment, devices, and components being used in the industry such as vector network analyzers, RF amplifiers, and RF filters. Figures 3 and 4 illustrate the breakdown of topics covered in each of the first two courses.

❑ RF Signal Generator and Spectrum Analyzer
- RF Frequency
- RF Signal Generation
- Signal Transmission
- Transmit and Receive Power
- Oscillators
- Signal Mixing – RF Mixer
- Harmonics
- Signal Bandwidth
- Noise Floor
- SNR

❑ Vector Network Analyzer
- Calibration
- Complex Impedance
- Smith Chart
- VSWR and Reflection Coefficient
- S-Parameters
- Antenna Characterization
- Return and Insertion Losses
- Transmission Line Characterization

Figure 3: Topics in RF Course 1

❑ RF Filters
- Bandwidth - VNA
- Insertion Loss - VNA
- Group Delay – VNA

❑ RF Amplifiers
- Gain, Output Power – VNA and SG
- Frequency Response – VNA
- Harmonics and IP3, 1-dB Compression
- Noise Figure – VNA and Noise Source

❑ Coax
- Characteristic Impedance - VNA
- Signal Loss - VNA
- Fault Detection - VNA
- RF Connectors – VNA

- Coupler, Combiner, Splitter
  - Characterization - SA
  - Insertion Losses

Figure 4: Topics in RF Course 2

The third and final course in the program is the senior capstone project. The students are required to choose their projects in various areas of RF engineering. Each project group must have between two and four people to work together. The restriction on the number of group members to learn and encourage teamwork. The course requirements are illustrated in Figure 5.

❑ Requirements for Senior Capstone Course

- 2 – 4 members per project group
- A project must be related to topics in RF engineering
- A project manager per group
- The project advisor must approve a project proposal
- Each member must have distinct roles and responsibilities
- Submit a weekly project journal with the progress made and issues and your resolutions
- Submit a project test plan for approval
- Demonstration of your project at the completion
- In-person project presentation to faculty and other students in the program
- Final report including BOM (Bill of Materials) and cost analysis must be submitted

Figure 5: Course Requirements for Senior Capstone Project

Possible areas of project topics can be:

- RF Test automation
- RF device performance improvement
- A standalone product with RF components and assemblies
- Antenna design improvement
- A simple end-to-end wireless communication implementation with performance characterization
- Test equipment development (Single or multiple types of measurement)

The student learning outcomes upon completion of each course are as follows:

RF Course 1:

1. The students will understand and use engineering quantities and units used in RF engineering.
2. The students will use RF signal generator, spectrum analyzer, and vector network analyzer for common RF measurements available from the test equipment.
3. The students will understand common RF measurement results and use them to characterize the basic performance of the devices under test.
4. The students will understand the importance of ESD (Electrostatic Discharge) and be able to properly monitor and use ESD protection system.

RF Course 2:

1. The students will understand the characteristics and performance parameters of various passive and active RF components.

2. The students will use proper test equipment for various passive and active RF components.
3. The students will detect and diagnose faults in various RF components.
4. The students will identify and properly use various RF components.
5. The students will predict the output RF characteristics of various RF components.

RF Course 3: Senior Capstone

1. The students will understand the "product development" process and the concept of "Optimum Performance Design".
2. The students will understand the practical project management techniques.
3. The students will work in teams for the design implementation and written/oral presentation of the Senior Project.
4. The student will systematically diagnose and troubleshoot technical issues in the project.

Education – Assessments

As a new instructional approach is used in RF Courses 1 and 2, there needs to be a different assessment method to be able to properly measure the outcome of the student learning objective. The assessment for these courses must be centered around measuring the practical knowledge of how the RF test equipment is used and the physical interpretations of the test results. To achieve the proper assessments for the skills the students are to acquire through these courses, after each topic in the courses, a practical lab test will be given with a set of topic-related measurement tasks and questions to verify the understanding of the measurement results. The measurement tasks are compiled based on surveys of the most common RF measurements routinely performed by RF engineers. This will ensure that the assessments are in line with the practical instruction approach and that the students are prepared for the real-world applications of what they have learned. The assessment flow is illustrated in Figure 6.

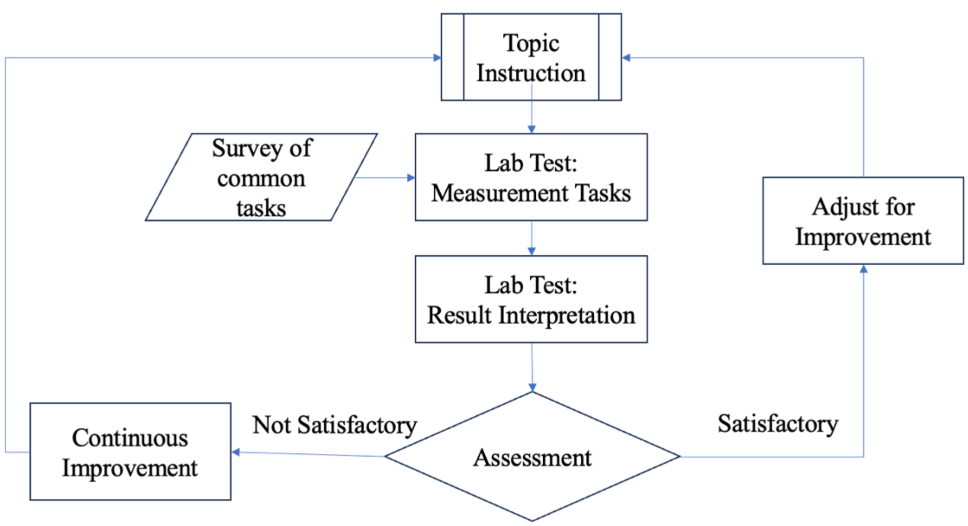

Figure 6: Assessment for RF Course 1 and 2

For RF Course 3, the senior capstone must be assessed in terms of achievement in professional project management, technical competency, and both oral and written communication skills. The level of achievement in project management can be assessed by requiring a weekly report of project status, with which the timeliness of task completion, risk management, and resource allocations are evaluated. Technical competency is evaluated with the completeness of the technical features of the project including alternative implementation of the features than in the proposal. The written communication skill is assessed by the final technical report in terms of technical writing proficiency, clarity, and organization. Oral communication skills are assessed by the audience to the project presentation so that a more objective assessment can be achieved. The final presentation will be assessed in three different categories, clarity of the presentation, delivery of technical contents, and level of interactions with the audience through the questions and answers exchanged. Figure 7 illustrates the assessment flow for the course.

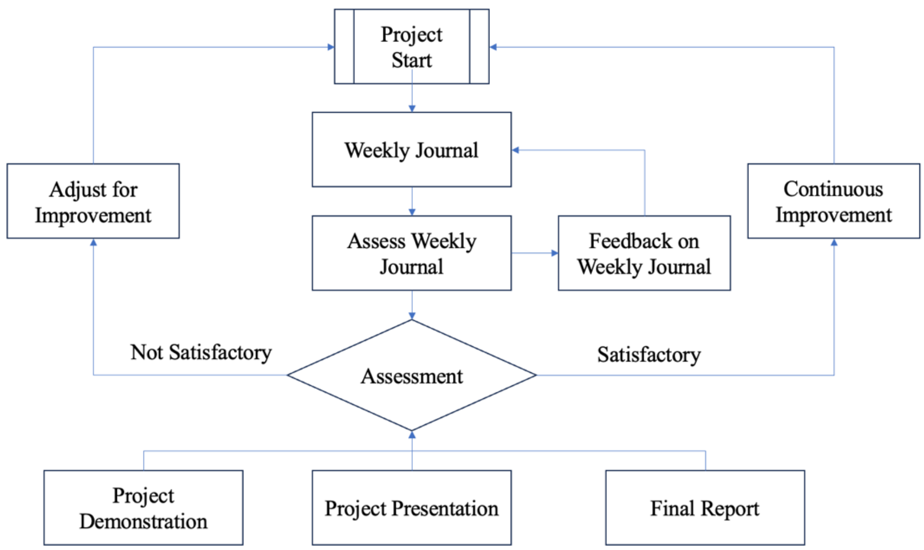

Figure 7: Assessment for RF Course 3, Senior Capstone

Education – Lab Equipment

As the coursework in the micro-credential program is designed around core RF equipment, acquiring, and maintaining the equipment to the industry standard is quite important to keep the micro-credential relevant to the current technologies. The equipment for RF measurements generally costs more than the equipment used in other areas of electrical engineering technology [3]. Financial support from the college administration, the industry, private donors, or educational grants should be sought to properly set up the lab to maximize the benefits the students receive through the micro-credential.

The equipment listed below is acquired based on the feedback from many RF engineering experts.

- A dedicated RF engineering lab with eight lab stations
  - Vector Network Analyzer: Rhode & Schwarz ZNL 6 with calibration kit, C-Band
  - Phase Stable Cables – Rhode and Schwartz

- Spectrum Analyzer: Rhode & Schwarz ZN-Z135, C-Band
- RF Signal Generator: Rhode and Schwarz SMB100B C-Band
- RF Power Meter with Power Head: Boonton PMX40
- Noise Source: Noisecomm NC346
- Microscope: Olympus SZ6145TR
- Oscilloscope, Multimeter, DC Power Supply
- Additional set with K_a-Band capabilities for research and technology development

Figure 8: RF/Microwave Lab Equipment

Preliminary Results – Assessment and Feedback from RF Course 1

The RF Course 1 was run as a pilot course in Fall 2023 with 8 students enrolled. The assessments for the student learning outcomes included two exams and four hands-on tests with a target for performance of 70% of students earning a score of 75% or higher. 7 students met or exceeded the target performance. The end-of-semester course survey showed that 100% of students either strongly agreed or agreed on the course organization, positive learning experience, and relevance to acquiring real-world skills. The most common feedback was to have more hands-on exercises. A shortened version of the course materials was also presented to a group of entry-level RF engineers from a local RF company in three full-day seminars. The company management reported that the participants were able to perform their daily tasks more independently than before the seminars and offered internship opportunities for the students completing the micro-credential. The course is scheduled again for Fall 2024 with the expected enrollment of more than 14 students.

Conclusion

This paper presents a micro-credential in RF engineering with a detailed implementation process. The micro-credential program offers excellent opportunities with competitive advantages for engineering technology students by integrating education, experience, and certification of technical skills. The framework built for the micro-credential in this paper can be used to create micro-credential programs in other fields for students in engineering technology. The micro-credential program should strive to not only be successful as a certificate offering but also be of valuable learning experience to our engineering technology students with a constant cycle of feedback and adjustments. In conclusion, the micro-credential in RF can make a positive impact on both student recruitment for the degree program and job opportunities for engineering technology students in RF industry by offering education in essential and practical skills, applied learning experience through projects and internships, and recognition of acquired skills through the micro-credential certification.

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