Outcomes-based Concept Module Development for Systems for Smart Communications

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I. Introduction

Smart communications technology has seen increased interest in a variety of applications such as smart antennas, satellite communication systems, intelligent transportation systems (ITS), and wireless LANs. The current research in this area encompasses many aspects of antenna and receiver design, antenna control designs, high-speed data conversion (digital to analog and analog to digital) and digital signal processing (a system block diagram is shown in Figure 1). Unfortunately, as with many emerging technologies, it is difficult for students to obtain and grasp the fundamental concepts of smart communications since textbooks have yet to be developed, the volume of research work is large and appears in numerous journals, and the technology spans several disciplines of electrical engineering.

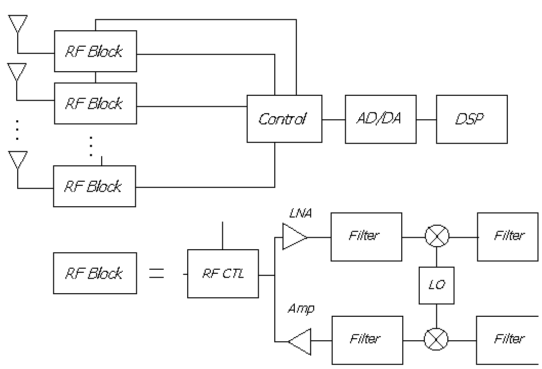

Figure 1. Block diagram of a smart communications transceiver system

The authors are developing, with the support of an NSF CRCD grant, a series of educational concept modules covering both basic and advanced topics in smart communications technology, focusing on microelectronics, antennas and the signal processing elements. This set of topics was chosen to leverage the broad research expertise at the participating universities, which represent a fertile background for introduction of the technology to advanced undergraduate students as well as first year graduate students. The group of participating universities represents a broad spectrum of educational institutions, which will help in making these smart communications concept modules suitable for use in small, medium and large college and university electrical and computer engineering programs. The purpose of the modules is to help both students gain the knowledge they need to contribute to the research and development of smart communications systems, thereby accelerating the integration of this emerging technology into practice.

Initially it was recognized that the broad multi-disciplinary nature of smart communications systems (SCS) would generate a tremendous amount of educational material in a variety of instructional formats. Therefore, a structured approach had to be taken to develop the modules in a systematic way, while at the same time, developing the module topical content with both learning outcomes and outcomes assessment practices from the outset. This paper will report on the early steps followed as part of the development of the structured, outcomes-based concept modules and associated reinforcement exercises in these modules. The structure is based on the use of content templates that specify the student learning outcomes and the methodology the instructors will use to lead the students to the achievement of those outcomes. Rather than discussing the structure as a theoretical exercise, the paper will show how this structure is being used to implement the SCS concept modules. Examples of completed templates will be shown, with extensions to the other topical areas in smart communications.

II. Module Development for Smart Communications: The Early Stages

The focus areas of the educational module development are in RF CMOS microelectronic system design, digital signal processing for smart antennas and low profile antennas for smart communications. These concept modules will ultimately take the form of video lectures both in hard media format such as CD ROMs as well as web-based streaming media, electronic lecture notes on the material, CAD or other simulation problems and projects meant to help reinforce the material so that students achieve a deeper understanding, and extra material for course instructors. The self-contained concept modules will be developed in conjunction with current undergraduate and graduate courses in the ECE program as well as newly developed courses. It is also anticipated that the modules will be used by practicing engineers wishing to learn more about smart communications.

IIA. Module Content Identification

The first step in the SCS module development was the identification of the major content areas the modules would cover. The goal in this step was to distill the high-level topical research areas that students would need as background in SCS technology into a series of self-contained instructional concept modules. Completion of this series of concept modules would provide the information students needed to read (and even more importantly, understand) the current state of research in SCS content areas. The module content development was divided among the project faculty who provided the major input on the topical content based on their research expertise as well as their knowledge of current research in the field. The list shown below illustrates the major content areas that were identified.

CMOS Microelectronic Systems
A1: Overview of HF smart communication systems
A2: CMOS design principles
A3: Integrated RF amplifier design
A4: Integrated RF control

A5: Integrated RF filtering
A6: Integrated RF mixers
A7: Integrated RF oscillators

Digital Signal Processing
B1. Wireless channel characteristics, channel impairment and fading properties
B2: Channel estimation and measurement
B3. Channel equalization
B4: Space-time coding
B5. Smart antennas

Low Profile Antennas
C1: Printed, fractal and other planar antennas
C2: Bandwidth enhancement and multi-band techniques
C3: High-gain techniques
C4: Evolutionary computing techniques for planar antenna optimization
C5: Modern antenna measurement

IIB. Developing Learning Outcomes for the Modules

Each major topic area was further divided into a number of detailed content subtopics (numbering from five to nine) that would correspond to lectures, demonstrations or other instructional methodologies that would address key components of that major topic area. These subtopics were further organized to indicate the associated learning outcomes, the subtopic highlights, the application exercises that will be used for content reinforcement, and the assessment for that particular subtopic. The subtopics were designed to give a coherent view and complete representation of the topic, where the flow of information from one subtopic to the next and across all subtopics can be closely observed.

Preliminary learning outcomes and assessment methods for each module subtopic in the area of smart communications were developed in consultation with published guidelines [1] and the Villanova University Institute for Teaching and Learning (VITAL). The learning outcomes use language that specifically indicates the skill set students will have at the completion of each subtopic. Some examples of learning outcomes already developed for SCS modules are:

- Students will calculate efficiency and PAE (power added efficiency) of class A and B amplifiers and compare with simulations (CMOS Microelectronic Systems);

- Students will successfully calculate the channel capacity improvement achieved by using multiple antennas (Digital Signal Processing);

- Students will use two main analytical models for a first order design of microstrip antennas (Low Profile Antennas).

The next step in helping students achieve these learning outcomes was to present the subtopic content with those outcomes in mind. At the present time, the development of each subtopic in the program follows the general outline indicated below.

- 15 to 20 minute video lectures and electronic notes that accompany a lecture or demonstration on a specific subtopic and focused toward the learning outcome associated with that subtopic. Each concept module (indicated as Module A-1, etc.) will have a varying number of these 15 to 20 minute subtopics (between five and nine).
- A mechanism for reinforcing the learning objectives presented in the 15 to 20 minute subtopics. These mechanisms may take the form of generated simulation models for use in design-oriented laboratories/practicums and will be put in such a form as they can be imported into readily available software such as MATLAB or microwave and RF CAD tools (Sonnet, Serenade, ADS or Microwave Office, SPICE). Other mechanisms might include videos of complex measurement practices and procedures or a comparison of calculations and simulations with experimental data.
- Assessment of student learning is handled by introducing variations in the reinforcement exercises and asking the students to successfully complete the assessment exercise.
- The instructional media needed to most effectively deliver the subtopic content have been identified as Video Lecture Tape, Computer Screen Output, Document Camera, or CAD Software; this list completes the material needed for subtopic presentation.

With each SCS concept module containing between five and nine subtopics, the entire concept module suite will have at least 125 subtopics. The next section presents the approach taken to organize this large volume of instructional material in SCS education.

IIC. Subtopic Organization: An Example

A series of templates were created to be used by the module developers to tell, at a glance, how the modules and their subtopics fit into the larger picture, if there is undesired content overlap, or if additional content coverage is needed. At Villanova University, two templates were developed, with input from VITAL, to organize the subtopic content as detailed in the previous section. At the higher level, a *Major Topic Area Organization Form* (Appendix A) was used as a rubric to organize the major module topic area into smaller, single lecture or demonstration subtopics. Completion of the form requires the instructor to identify the subtopic areas need to understand the major topic area. An example shown in Appendix A shows the subtopics deemed necessary for students to understand the operation and design of Integrated CMOS RF amplifiers.

The detailed subtopics as listed on the *Major Topic Area Organization Form* are more easily developed once they have been identified. The results of this development are then used to complete a *Subtopic Organization Form,* as example of which is shown in Appendix B. The example shown is for the lecture/demonstration for the Integrated RF Amplifier subtopic where nonlinear amplifier specifications are first defined and then reinforced with SPICE simulations of those specifications.

A novel part of this SCS project, and generally good practice in any educational endeavor, is the extensive use of reinforcement material to help students achieve the learning outcomes. In this project, the reinforcement material can take many different forms. A representative list of some reinforcement material for the Smart Communication Systems project is shown below:

- measurement data from custom integrated circuits that will be provided to module users to compare with simulation results (CMOS Microelectronic Systems);
- use of a wireless communications test-bed to transmit/receive user-controlled signals through various environments (indoors, outdoors) to observe the effect of the channel in relationship to the transmission rate (Digital Signal Processing);
- observe (through video) measurement techniques and procedures for microwave and millimeter wave low profile antennas using an indoor compact antenna range (Low Profile Antennas).

The list of major SCS content areas and their associated subtopics (with learning outcomes, assessment and reinforcement exercises) is extensive and will be available on the project website[1].

III. Conclusions

The completion of the templates can initially consume a large amount of time. Instructors have to become familiar with the templates and to learn how to articulate their outcome achievement goals into the template format. However, after this initial investment in time, revisions are more easily done since the entire educational content can be seen at a glance. This structure becomes paramount when a multi-topic, multi-instructor, multi-institution educational development effort is undertaken, and the structure should be implemented at the project outset. Student learning outcomes then become the driver for the content, exercises and content assessment. The framework is useful for identifying undesired content gaps or overlap. Ultimately, the implementation of the modules and their associated subtopics should proceed more smoothly than if a more *ad hoc* approach toward module development is undertaken. Time will tell.

Acknowledgement

This material is based on work supported by the National Science Foundation under Grant No. 0203459.

References

1. Gronlund, N., How to Write and Use Instructional Objectives, 6th ed., Merrill/ Prentice Hall, 2000.

[1] http://rcaverly.ee.vill.edu/crcd/public.htm

Appendix A

Major Topic Area Organization Form

Major Topic Area: CMOS Microelectronics	Area Coordinator: Caverly
Sub Area Number: 3 Sub Area: Integrated RF Amplifiers	Date:

Sub-topics: topics for 15 to 20 minute lectures/demonstrations

Sub-Topic	Content
A	RF Amplifier Classes (A, B, AB, C); terminology (PAE, η)
B	Detailed terminology (PAE, η, IMD, HD, IP), Amplifier S-parameters
C	Transistor types for integrated RF amplifiers – FET, CMOS
D	Amplifier design using S-parameters
E	Simple single stage amplifiers – single FET, current source pull-up, passive pull-up topologies
F	Cascade amplifiers – design, interstage coupling, matching
G	High current output stages for amplifiers – FET, CMOS
H	Active matching circuits (Z_0 active match)

Appendix B

Subtopic Organization Form

Major Topic Area: CMOS Microelectronics	Area Coordinator: Caverly
Subtopic Area Number: 3B Subtopic Area: Integrated RF Amplifiers	Date:

Lecture/Demonstration Materials Required (Yes-Y, No-N)

(if yes, determine in the table below the materials required)

Video Lecture Tape	Computer Screen Output	Document Camera	CAD Software (name)	Other (specify)
X	X	X	SPICE	

Subtopic Learning Outcome(s)

Students will be able to simulate nonlinearities in RF amplifiers and compute distortion intercept point from simulated and measured data.

Sub-topic Highlights

A. Other amplifier terminology beyond PAE and η: S-parameters for a simple amplifier using simplified FET model, amplifier linearity.
B. Define, calculate S-parameters for the simple FET amplifier model.
C. Further define linearity issues: Harmonic Distortion (HD), Intermodulation Distortion (IMD), Total Harmonic Distortion (THD), intercept point.
D. Introduce amplifier linearization techniques – feedforward, feedback

Application Exercises (Reinforcement)

1. Using a SPICE template, simulate two-tone HD, IMD for a simple MOS RF amplifier.
2. Compute THD, IP from HD, IMD simulation results.
3. Compare the simulated amplifier results with provided measurement results from an actual Class A 50Ω RF amplifier in CMOS technology.

Assessment Method(s)

Students will compute IP and THD from SPICE simulations on a Class B 50Ω RF amplifier.