# Electromagnetics Challenges in a Telecommunications Engineering Curriculum

Sam Henry and Orlando Baiocchi

***Abstract*— Most conventional Electrical and Computer Engineering programs offer only one basic course in Electromagnetics. Very rarely are students exposed to complex propagation and radiation problems that pertain to real world applications. One such important example is terahertz remote sensing, which requires advanced knowledge of electromagnetic propagation. This paper proposes an undergraduate electromagnetic course sequence model that not only addresses these needs, but also offers the flexibility to include additional topics as demanded, like the latest 3-D numerical tools used in electromagnetic simulation.**

***Keywords—Education, Electromagnetics, Wireless, Wireless Sensor Networks, Terahertz.***

## I. INTRODUCTION

### *A. Background*

Traditionally, most Engineering core curricula contain only one basic course in Electromagnetics covering static fields, Maxwell equations, transmission lines, plane waves, waveguides and antennas [1]. Rarely are undergraduate and sometimes even graduate students exposed to the complex electromagnetics that pertain to real world problems. The Telecom engineer of the future will need that exposure as well as the knowledge of more specific applications to modern wireless communication. We propose a course sequence that offers this traditional theoretical course and an additional two courses (all taken in the junior year) that cover microwaves and current applications in electromagnetics from optics to radio devices (the electromagnetic spectrum is shown for your convenience in Figure 1). All students in electrical engineering and telecommunications majors would take the first one or two courses in the sequence and if they chose the electromagnetics specialty track, then they would take all three.

A new wave of wireless technology has arrived. Look no further than ubiquitous wireless sensor networks that have been recently researched. Current systems have even been deployed all around the world measuring everything from temperature in remote portions of the globe to live traffic conditions [2]. However, wireless engineers working in this area are often not exposed to relevant topics needed for modeling in complex propagation environments.

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Another pertinent example of a recent wireless innovation is terahertz technology. Terahertz (THz - meaning 1 x $10^{12}$ Hz) is a portion of the electromagnetic spectrum that resides between the infrared and microwave regions, as shown in Figure 1.

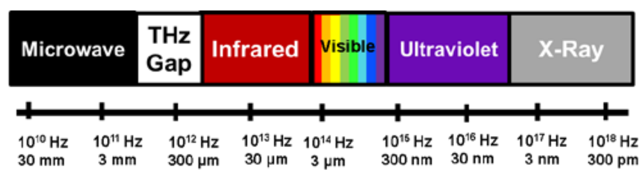


**Figure 1: Electromagnetic spectrum showing the "THz Gap" in between the microwave and the infrared portions of the spectrum**

### *B. Introduction to THz technology*

With the improvement of ultra-fast laser technology, THz sources and detectors have been increasing in efficiency since the 1990s [3, 4]. Unsurprisingly, THz time-domain systems have entered a period of significant innovation as researchers continue to find new applications. Figure 2 shows the number of articles per year retrieved in Compendex Search containing the words "THz" or "terahertz" in the title of the publication. The curve shows an almost exponential increase in publications, which is an indicator for the overall interest from the scientific and engineering communities.

THz wavelengths are small enough to contain meaningful imaging resolution, while at the same time long enough to penetrate many nonpolar packaging materials and clothing. THz frequencies are also non-ionizing and relatively low power; therefore have virtually no effect on objects that are inspected. For these reason, lower frequency THz systems have largely replaced X-rays as primary personnel scanners at airports around the world. In addition, they have the well-publicized potential to detect explosives under layers of packaging or clothing [3, 4].

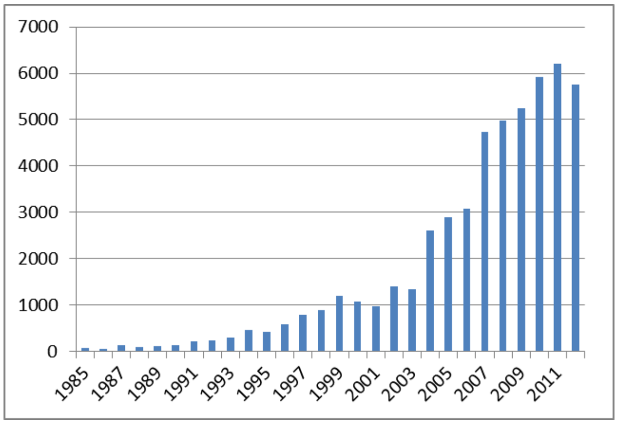


**Figure 2: Number of articles per year retrieved in Compendex search containing the words "THz" or "terahertz" in the title of publication or conference paper.**

While THz imaging has perhaps been best known for potential in security, there are a growing number of non-destructive applications in manufacturing. For example, researchers have recently shown THz frequencies to be effective in detecting faults in integrated circuits [5]. THz systems have also been used to detect cracks in manufactured solar panels [6], to monitor the drying process of paint on automobiles [7], and to investigate defects in fiber composites, such as those used in the latest Boeing 787 Dreamliner [8, 9]. Past examples also include significant work by the National Aeronautics and Space Administration (NASA), inspecting defects in space shuttle foam [10].

THz imaging and wireless sensor networks are two great examples of direct modern applications to electromagnetic theory. And both of these exciting fields are multidisciplinary, attracting material scientists, physicist, and engineers. It makes sense to include a course that specializes in these advanced topics following a core theoretical course that covers basics.

## II. CURRICULUM

Currently, to the best of our knowledge, there are no undergraduate or graduate degree programs (or certificates) that specialize in specific electromagnetic applications to telecommunications, THz technology or wireless sensor networks. While we do not necessarily believe these warrant full degree status, it does make sense to develop a core curriculum that allows students to specialize in specific electromagnetic topics, especially in institutions where active research in these areas is taking place. We propose a three-course sequence to be taken during the students' junior (or potentially senior) years. The last course is modeled from a similar course offered at Portland State University in Portland, Oregon [11]. The three courses are outlined along with a brief description in Table 1.

TABLE 1: UNDERGRADUATE ELECTROMAGNETIC COURSE SEQUENCE

| **Fall** | **Winter** | **Spring** |
|---|---|---|
| ***Engineering Electromagnetics 1*** | ***Engineering Electromagnetics II*** | ***Engineering Electromagnetics III*** |
| ***Plane waves, transmission lines, antenna theory*** | ***Applications pertinent to telecommunications*** | ***Microwaves: striplines, passive and active circuits*** |

The initial part of the proposed curriculum does not differ what most programs currently offer, and can be delivered either as one single semester course or two quarter courses, as outlined below:

### *Engineering Electromagnetics 1*

*Fundamentals of electromagnetics including: static electric and magnetic fields, quasi-static solutions, Maxwell's equations for time harmonic fields, plane wave propagation, transmission lines and waveguides, radiation and antennas.*

The second component of the curriculum would include topics as outlined below. Depending of the range of topics covered and the model of instruction used in different schools, it could be delivered either as a single semester or a two-quarter courses. As with the initial course, the number of credit hours could be adjusted according to the specific needs of the academic model used.

### *Engineering Electromagnetics II:*

*Application of Maxwell's equations to relevant problems in telecommunications such as: pulse propagation in dispersive materials, optical fibers and optical communications, antenna arrays, diffraction and scattering, synthetic apertures and principles of radar, transients in transmission lines, electromagnetic interference and signal integrity, microwave and terahertz sensing, applications of terahertz technology, wireless communications, multi-path signal propagation, 2-D and 3-D mathematical solution techniques. Course content could include project-based laboratory activities and reading assignments from current publications.*

Still at undergraduate level, an additional course on Microwaves could be added as optional. Such course would have the advantage to provide a more direct, hands-on laboratory experience. Again, depending on specific needs and conditions, as well as on the laboratory facilities, it could be offered as a one quarter course, or be extended to a full semester.

***Engineering Electromagnetics III (Microwaves):***

*Quasi-TEM propagation, microstrip and striplines. passive microwave components, design of passive microwave circuits. active high frequency devices, microwave computer aided design, non-linear effects and nonlinear circuit design, introduction to MMIC design, superconductive transmission lines, MEMs and nanostructures. Course content could also include an introduction to 3-D full-wave simulation tools such as Ansys' High Frequency Structure Simulator (HFSS) or Agilent's Advanced Design System software (ADS).*

## III. CONCLUSION

In this paper we open the discussion on how to re-structure the electromagnetics sequence of courses in an electrical engineering program that emphasizes or specializes in Telecommunications. Our proposed model is flexible and can be easily adapted to different situations. But the main point is that a modern curriculum, to address the challenges of the rapidly changing technology, needs to include topics that are currently absent in most programs. In particular, we emphasize the introduction of terahertz fundamentals and applications. We hope that the Telecommunication community will engage in this discussion and, as a result, our students will be better prepared for the hi-tech industry jobs and for graduate studies.

## IV. ACKNOWLEDGEMENTS

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