

Numerical techniques in electromagnetics and communications

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**"Numerical Techniques in Electromagnetics and
Communications"
A PC based third year undergraduate subject for
Microelectronic Engineers.**

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ABSTRACT: The School of Microelectronic Engineering at Griffith University graduated its first engineers at the end of 1993. One of the two majors offered to students is Communications Engineering which includes the subject "Numerical Techniques in Electromagnetics and Communications". Exercises and assignments in this course are PC based. This paper describes the subject content, teaching methods, assessment methods and gives anecdotal evidence as to its success. Examples of assignments and solutions are presented.

INTRODUCTION

Griffith University was established in 1975 as the third tertiary institution in Brisbane with a charter to offer degree programs that were significantly different to other offerings in the city. Science (favouring interdisciplinary teaching and research covering mathematics and physics through to biology and biochemistry) was one of the first four faculties. In its short history, the School of Science developed considerable research expertise and equipment in surface science, solid state physics and electromagnetics. At the end of the 1980's there was increasing pressure from within the university to expand these offerings to include professional schools. The first of these was the School of Microelectronic Engineering which emerged from the School of Science and commenced recruiting faculty in 1988 with a first student intake in 1990. The four year degree program graduated its first students at the end of 1993. Currently the school has 11 tenure-track faculty staff, 250 undergraduate students and 10 postgraduate students.

What distinguishes this school from other engineering schools in Australia is the emphasis on electronics in all years of teaching. For example, in first year students take subjects in digital electronics and analog electronics. In second year students take the subject "Integrated Electronics" and design their first integrated circuit in third year. In parallel with this are optional subjects relevant to the education of communications engineers. The most relevant courses are given in Table 1.

COMPUTATIONAL ELECTROMAGNETICS

In common with the education of circuit design engineers in the school, it was regarded as essential that students could solve problems in electromagnetics and communications in a time effective manner. This includes problems in areas such as antennas, propagation and scattering. If

students gain these skills relatively early in their education, then their understanding of the later material would be enhanced.

Year	Communications subjects	Mathematics subjects
1	First year physics	First year mathematics
2	Electromagnetic theory Transmission lines	Continuous mathematics
3	Linear electromagnetics Numerical techniques in electromagnetics and communications Communications circuits and systems Data communications	Mathematics IIIC
4.	Advanced communications systems Optical communications systems	Complex analysis

Table 1: Subjects in electromagnetics and supporting mathematics

In planning the course, priority was given to minimising the computing education required, both in regard to using specific software and also the generation of large programs in C or Pascal, the two languages in which students have some background. The decision was made to use Matlab® on PC's for all programming applications. Thus the FDM and FEM assignments were conducted in this way, and the method of moments assignment was based on NEC2 (Burke and Poggio, 1981) running on a PC. The reasons for adopting this strategy include the following.

- * The low cost of the student edition of Matlab® allows extended student access.
- * The graphics facilities (3D, colour, contour and vector outputs) are very good.
- * The commands mesh, quiver, gradient and contour reduce the tedious manipulations of large data sets.
- * The learning time to edit, debug and execute .M files is very short.
- * There is a move to use Matlab® in a compulsory subject in second year so in 1994 students will start the course with a working knowledge of the language.

The teaching contact consists of 35 hours of lectures and 14x4 hours in the computer laboratory. Assessment is 60% based on marked assignments (20% for each of three assignments), and there is a 40% final examination. The lecture material covers the following topics:

Numerical methods for matrix calculations (minor exercises)
 Finite Difference Method (with a major assignment using Matlab)
 Method of Moments (with a major assignment using NEC2)
 Finite Element Method (with a major assignment using Matlab)
 Introduction to other numerical techniques (BEM, transmission line method)

Neutral atmosphere propagation (multipath, surface impedance, Fresnel zones, Babinet's principle)
Ionospheric propagation (MUF, Faraday rotation)
Antennas (arrays, network approach) (minor exercises)

The textbook used for the CEM section for the numerical techniques course is Sadiku (1992).

The laboratory hours are used both for un-assessed preliminary work before the assignments were issued and assignment work. An example of a non-assessed work sheet is given in the Appendix. This example is the first FDM problem students encounter, and has an analytical solution. Students are required to create a program which fills the matrix, implements the boundary conditions, solves the problem and plots the output data. The same tasks are required in the major assignments which are individualised for each student. The FEM and FDM assignments are limited to two dimensional structures, however, the method of moments assignment requires three dimensional interpretation. Marks are allocated in following way:

- 20% Problem definition (mesh generation, location of node points, boundary conditions, symmetry etc)
- 20% Method of solution (method of filling the matrix, matrix inversion technique etc)
- 20% The solution (presentation, explanation, plots, contours etc)
- 40% Solution verification (comparison with theory, simple models, number of points)

In this way emphasis is placed on the construction of flexible programs, interpretation and presentation of data, and most importantly, validation of the result. Assignments are marked by faculty and considerable feedback is provided. Some examples of these assignments and the methods of verification expected will be presented.

ANECDOTAL FEEDBACK

While no formal student survey work has been conducted, the following points were raised during informal discussions with students during 1993.

The communications major is perceived by students to be more difficult than the computer systems major, but generally more rewarding. There was some initial concern expressed by students about the learning of Matlab®. This was despite the un-assessed laboratory classes before the first assignment. As soon as the first assignment had begun, student interaction resulted in a rapidly developing set of skills. This may not be a problem in future years if students enter the course with a knowledge of Matlab®. The submissions for the first assignment (FDM) include 3D plots and contour plots in addition to solutions for quite large meshes of over 10^4 points. The weakest part of most assignments submitted was the verification section, although this did improve with written feedback from earlier assignments. At the end of the course, an unusual number of students made enquires about future work and also postgraduate studies in the area. This major has attracted an unusually high number of students and has provided them with a motivation to continue working in the area. This is in contrast with a trend away from

electromagnetics which has been quite common in other tertiary institutions in recent years.

References:

G.J. Burke, and A.J.Poggio, *Numerical electromagnetics code - Method of Moments*. Lawrence Livermore National Laboratory, UCID 18834, 1981.
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 Matlab® is a registered product from The MathWorks Inc
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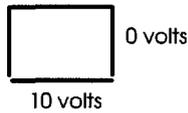
Acknowledgments:

The authors would like to acknowledge the enthusiasm of students in the course to date. Their enthusiasm is infectious to both faculty and other students. A visit to the school by Dr Ed Miller in 1992 proved to be a significant motivator for students contemplating working in the field of CEM and VEM.

Appendix:

The problem

Consider a 2D region enclosed on three sides by grounded conducting planes. The fourth side is an end plate which is insulated from the grounded sides and has a constant potential of 10Volts. Using the finite difference representation of Laplace's equation, calculate the potential distribution at 12 points inside the region, and so calculate the electric field at these points. Assume that the dimensions of the rectangle are 4cm x 5cm. Compare your answers with the exact formulation derived using the separation of variables method given in Cheng p 181-2.



Analytic Solution (from Cheng)

$$V(x, y) = \frac{4V_0}{\pi} \sum_{n=odd}^{\infty} \frac{\sinh(n\pi(a-x)/b) \sin(n\pi y/b)}{n \sinh(n\pi a/b)}$$

Solution comparison

Position:	a ₁₁	a ₂₁	a ₁₂	a ₂₂	a ₁₃	a ₂₃
FDM potential	4.49	5.86	2.11	3.09	0.86	1.32
Analytic potential	4.51	5.98	2.06	3.13	0.83	1.32