Education Notes

Note 1

25 August 1988

The Short Course: EMP Interaction and Hardening (EMP 201)

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Abstract

For five years now the EMP short course on "EMP Interaction and Hardening (EMP 201)" has been conducted with considerable success in terms of impact on the students. This paper discusses how the short course works. The various aspects include the faculty, course material, course structure, seclusion, student qualifications, and student participation. The course is strongly influenced by the university experience.

I. Introduction.

The short course "EMP Interaction and Hardening (EMP 201)" has been given seven times now. As this short course is unique in concept and various people have asked me why it is structured as it is, I thought it was time to write something about it. I would first note that before the first one of these courses was given in July 1983 (at New Mexico Tech in Socorro) there were many discussions concerning how to structure this course, particularly with K. S. H. Lee.

There is the subject matter. There are various aspects of the nuclear electromagnetic pulse (EMP) that could be taught. The most important consideration in this regard was what aspects were the most needed. Things like environment and simulation, for example, seemed to apply primarily to small groups of specialists. However, how EMP interacts with systems and what to do about it (hardening) seemed to be that aspect which had to be known by the largest group, these being the people in industry and government who were responsible for the design of EMP aspects of military and civilian systems. Furthermore, this part of the problem has much in common with other related electromagnetic (EM) problems such as lightning, high power microwave (HPM), electromagnetic compatibility (EMC), TEMPEST, etc. Because of the importance and difficulty of the problem EMP technology has led in this area, developing new and more rigorous concepts. (See the forward of [1].) This could significantly benefit these other EM areas.

The primary text for the short course is [1], including its previous printings. Since this is a public domain book this allowed the short course to be conducted on an independent basis in the usual academic sense. Professional scientific/engineering and academic judgement could prevail in the subject material and conduct of the course. Agency and company politics could be pretty much kept out. The actual sponsorship has been from SUMMA Foundation, a non-for-profit charitable entity, which sponsors the usual professional scientific things like symposia, publications, etc..

II. Short-Course Background.

Over the years there has been some evolution in what a short course should be, and there are various kinds, depending on the type of material presented. While there are some short courses which seem to be geared to "technicians" and involve hands on work, many others are primarily "presentational" in nature. In the latter case some body of technical information is to be imparted to a set of students. Each student may be given some documents containing portions of the course material. The faculty give lectures, usually using projected visual materials such as on transparencies with overhead projectors.

This basic approach of faculty lectures with supporting material seemed to be somewhat limited. Something seemed to be missing. All this material was flashing in front of the students, and while the students could later go back to source materials, still little seemed to be directly retained in the sense that they could apply (or even repeat) the information. After some number of these lectures, many students seem to become numb. (You may have noticed a glazed or bored expression).

Another way to look at this type of short course is as an extension of a scientific/engineering symposium. The papers are merely longer and the students sit through all of them.

III. Educational Background.

How do you structure a short course so that students learn the material presented? To do this let us appeal to experience, not only my own but that of humanity in general.

Since we are dealing with professional people (and sometimes graduate students) as the students, it seems appropriate to refer to the educational institutions which have been closest to the professional careers of such students, namely universities. Universities have evolved since the late middle ages, and the present state of this evolution should be considered as representing the most effective educational means for educating (among other people) scientists and engineers. If we know of a better way that was actually practical, presumably we should adopt that. As it is we should look to the university educational experience and adopt what concepts and techniques that we can.

Universities not only have lectures, they also have homework (problem solving in scientific and engineering disciplines) and examinations. Grades are given usually based on both assignments and examinations. While there are some students who do not need these goals, experience has shown that most students do need these. University degrees are generally not given for mere attendance, but upon demonstration to the faculty of some degree of mastery of the material by the student.

As we go on from undergraduate to graduate school the degree of required performance is increased. Oral examinations are required of the students so that the faculty can better probe the students' degree of preparation. Graduate seminar courses are introduced in which the graduate students are required to present topics of interest (such as current research) to the faculty and other students. At the highest level the student is required to defend his thesis, the results of his own independent research, before the faculty, his peers-to-be.

IV. Electromagnetics Background.

The course we are considering has an essential difficulty in that it involves electromagnetics. Normally one is introduced to this in physics 1 or 2. In about junior year electrical engineers and physicists take an EM course, but this may involve basically statics, simple antenna radiation, plane waves, maybe simple waveguides. In graduate school electrical engineers may (not often these days) take an EM course addressing more advanced topics (green functions, integral equations, arrays, etc.). Physicists also take an EM course, but one more oriented (unfortunately for our purposes) to particle physics.

Now in a short course one cannot cover all of the above material and then introduce the students to EMP interaction and hardening. The above (at least the basic portions) must be presumed if we are to discuss the subject of concern. As discussed in the Foreword to [1] there are various basic EM concepts which one must master if he is to apply electromagnetics to our class of real problems.

This leads to one of the features of this short course. For the important class of students, the participating students, we require that they have some electromagnetics background so that they have the basic concepts on which the short course can build. In academic parlance, there are prerequisites.

V. Course Structure.

The structure of this course combines the concepts of faculty lectures, problem solution by the students, and student presentations before the faculty and other students (graduate seminar and examinations). Referring to Appendix A, we see the basic outline.

The first full day (day 1) is devoted to faculty lectures corresponding to part 1 of the text. These concern general concepts that will be used throughout the course; they cover the techniques which will be used in the analysis of the kinds of the problems which come later. The first lecture is merely background information concerning EMP environments plus some history. The second topic is EM topology, the most important in the course as it provides the basic conceptual structure for the entire subject of interaction and hardening. It is the organizing principle for part 2 of the text and the second through fourth days of the course. The afternoon is devoted to more specific techniques for description and computation: integral equations, low-frequency and late-time methods (dipole and quasi-static approximations), and mid-frequency and intermediate-time concepts (singularity expansion method (SEM)). One might also consider the subject of transmission-line networks on day 4 as also appropriate for day 1 since it is also general in scope. However, it also fits very well with just one topic in internal interaction so that it can also go here very well. Furthermore, time constraints on the first day make this choice more practical.

Days 2 through 4 are devoted to major subsets of the interaction process, beginning with the outside (external interaction) and working inward. This corresponds to part 2 of the text. The topics are those encountered in the coupling/propagation/penetration description of the EM interaction in the topological sublayers of systems. It is at this point that the students contribute by presenting the analysis of particular pieces of the problem. The student presentations follow a faculty lecture of more general scope.

Day 5 puts the subject back together. The student presentations cover hypothetical system problems involving a signal that gets somewhere of concern in a system (where it might produce damage or upset) from an external high-altitude EMP environment such as would be encountered by in-flight and ground/water based systems. Here students see what EMP actually does (with numbers). Furthermore this forms a model for the students of how to approach real-system-EMP problems. The afternoon of this day is devoted to wrap-up lectures by the faculty involving questions of design practice, including such topics as specifications, subsystem design, etc.

There are other parts to the course structure besides the schedule of subject presentations. Consulting Appendix B, note day 0. Students and faculty arrive in the afternoon. There is registration involving name tags, residence room assignments, and distribution of course text material. After cocktails and dinner the course begins in earnest. First the students and faculty introduce themselves and give a little background information concerning themselves. Then the course director discusses how the course is to function and what to expect. The director finally organizes the students into groups which will work together at group tables. They sit together at these tables during the lectures and student presentations. Each group is organized so that it has a diverse set of students. As much as possible, students from the same country, same company, same gender, same type of employment (industry, government, university), etc. are split up and distributed among approximately equal groups. This distributes the various talents, backgrounds, viewpoints, etc. among the groups. The things of greatest common interest in each group are the course subject and the group performance in the course. This introduces an element of competition among the groups.

The number of groups is three or six, depending on the number of students (particularly participating students) so there may be four to seven students in a group (and hence at one table or table cluster). Approximately each half day, the group locations in the lecture hall are rotated so that each group (particularly the group scheduled for presentations) is in front about the same amount of time. Note in Appendix A there are six times for student presentations. Depending on three or six groups each group presents twice or once respectively.

As one can see from this, the maximum number of participating students is about 36, giving say six to each of six groups and requiring six presentations (a lot) during each presentation period. The minimum number of participating students is about 12, giving say four to each of three groups and requiring four presentations (enough) during each presentation period. The number of auditing students is limited by having no more than about seven students total in a group. With six groups (implying about 24 participating students or more) this would limit the total number of students to about 42. Note that the lecture hall has to accommodate the tables as well as the students and faculty (including a table for them) plus screens, projectors, chalkboards or markerboards, etc.

Each regular day of the course there are important features to the structure besides the presentations. Meals are taken together as this is another opportunity to talk about the material. Similarly, the cocktail period gives the students a chance to relax while what? (You guessed it, talk shop again!) The time after dinner is scheduled for preparation of assignments, although his happens at all free times including coffee breaks, cocktails, before breakfast, etc. Beginning day 1 at the end of lectures assignments are given for the next two group presentations, these presentations normally occurring the next day. Groups are also assigned to have first crack at questioning the presenters (participating students) in other groups. After these questions other groups get to ask questions, and after that the faculty gets to ask questions. So the students are quite busy.

The course ends with a graduation banquet on the evening of day 5. Besides a special meal each student receives a diploma, a class photo, and a list of the students and faculty. The festivities usually go far beyond this with toasts, special awards, poems, songs, skits, etc. limited only by the not-very-limited imagination of the students and faculty. (Remind you of school, does it?)

VI. Student Participation.

As should be clear by now student participation is fundamental to this course and one reason why they learn so much. Participating students are recognized with a special diploma. They are required to make presentations based on one of the problems assigned to their group for the time period of concern. They are further expected to ask questions of the other students (and perhaps the faculty as well).

Knowing that they are to make presentations of particular examples related to the faculty lectures seems to stimulate the students attention and stimulate questions. Furthermore, the students in each group discuss the problems among themselves to decide who takes what problem, and then they often help each other. I am reminded of the stated opinion of some of the Caltech faculty to the effect that the students teach each other. They also seek out the faculty who respond with various hints.

There is a second category of students, the auditing students. This category is primarily for managers who want to be exposed to this course to get some appreciation for what EM interaction is about. Usually because of their lack of an appropriate technical background they are not suited for the technical presentations. However, on rare occasions there are persons who are qualified, but just overly shy and do not want to make a presentation. The auditing students represent a small minority at the course. They are distributed among the groups where they help out with questions and discussion.

VII. Faculty.

Normally we try to have six or seven faculty at each course. One reason (not the most important) is so that each faculty member should be required to present no more than two or three hours of lectures. It should be noted that the basic course structure in Appendix A usually has some extra time after the student presentations which is quickly filled by various faculty who have lots of extra (but related) material. However, it is very important that each faculty member cover the basic concepts in each of his assigned lectures, instead of some topic of his recent research (which he is just dying to talk about).

A more important reason for the number of faculty concerns the different insights each one brings to the subject matter. All are experts, but each specializes differently. Some are more mathematical while others are experimentally oriented. They serve as role models for the students and relate different experiences in the numerous informal discussions that are going on all the time that there are not formal lectures.

While the harried course director is keeping things moving and on schedule, the faculty also pitch in on various other chores. Foremost among these is the preparation of problem sets for the students. These sets are cumulative with modifications being made to old problems and new problems being added.

The initial and primary source of faculty has been those involved in the preparation of the text [1]. However, as time goes on various EM professors and other starring students have been added to the rolls.

VIII. Seclusion.

In order to have the students concentrate their attention on the course it is best to minimize distractions. In the evenings it is best if there is nothing to do but course-related things. Thus, we tend to avoid the big city. ("How are you going to keep them down on the farm, after they've seen Paris?") To the extent feasible we would like there to be nowhere of interest nearby to go away to.

In addition, we would like the students and faculty to be together almost all their waking hours. It is best if the dining facility, lecture/study hall, and sleeping quarters are in immediate proximity, or at least within walking distance. If a student needs to get something from his room, then his absence is minimized. The faculty and students become one community or extended family with lots of camaraderie. (The limericks [2] are but one example. Perhaps you have heard of the "Mad EMP Party" at the Ann Arbor graduation banquet, or the No-Bell Prizes at Socorro and Interlaken?)

If this sounds something like a university, don't be surprised. The short course is often held at a university. I remember one ideal situation (as described above) in which we essentially took over one of the colleges of Nottingham University during the vacation period. (Does Robin Hood ring a bell?)

The short course has also been referred to as an EMP monastery. Perhaps this is associated with my Caltech upbringing, that place sometimes being described as a monastery to science and engineering. The interested reader can investigate the development of universities from monasteries in the late Middle Ages.

Appropriate choice of facilities also keeps the expenses down, allowing a high faculty-to-student ratio. There is a lot of dedication on the part of the faculty since they only receive reimbursement for their expenses plus a small honorarium (if there is a surplus).

IX. Concluding Remarks.

I do not mean to say that this model is the only model for a short course. However, it appears the best so far to handle certain kinds of material. I base these observations on practical experience. I have no formal education in educational theory, but then neither have most professors of electrical engineering and physics. For other kinds of material and types of students some other model may be more appropriate.

In developing this educational model, various aspects (as in the section headings) have been considered. They seem to interweave and have some kind of symmetry. Perhaps this subject should be treated by group theory.

I would like to thank many people, and especially K. S. H. Lee, for many useful observations and discussions concerning this short course, and for participating with me on this great experiment. It has been a lot of hard work, but a lot of fun too. I would also like to thank Raj Mittra for what I have learned, especially how to make color transparencies.

X. Epilogue.

"...and therefore, never send to know for whom the bell tolls; it tolls for thee."

by John Donne

References:

1. K. S. H. Lee (ed.), EMP Interaction: Principles, Techniques and Reference Data, Hemisphere Publishing Corp., 1986.

2. T. Karlsson (ed.), Limerick Interaction: Principles, Techniques, and Reference Data - A Compleat Concatenation of Limerick Technology from the EMP 201 Courses, EMP Limerick Note 1, June 1988.