Teaching Electrical Engineering via Television

Timothy Pratt[1]

Abstract – Teaching Electrical Engineering to graduate students who are working full time in industry via television presents some special challenges. This paper traces the history of the Commonwealth Graduate Engineering Program in Virginia from the early days of C-band satellite distribution of classes to the current Internet compressed digital video system, and discusses the different demographics and learning styles of the distant students. The production of graphic materials for transmission over such links requires considerable care if effective communication between the instructor and the student is to be maintained. Examples of good and poor practice are given, and guidance is provided on best practices in the preparation and transmission of material containing graphics and equations.

Keywords: Televised teaching, graphic materials.

THE COMMONWEALTH GRADUATE ENGINEERING PROGRAM

The Commonwealth of Virginia has two major tier one research universities, Virginia Tech (VT), located in Blacksburg in SW Virginia, and the University of Virginia (UVA), located in Charlottesville in central Virginia. Virginia's high tech industries are largely concentrated in the Washington DC metropolitan area, where it is thought that there are now more engineers than in Silicon Valley. There are a number of large military bases in Virginia, and the Naval Surface Warfare Center (NSWC) in Dahlgren is the largest single employer of engineers and scientists in the state. All these high tech employers are located more than 100 miles from UVA and more than 200 miles from VT. The large distances between working engineers employed by industry and government, and the tier one universities offering advanced degrees made acquiring a master's degree difficult once BS graduates entered the workforce.

In 1984 the State Council for Higher Education in Virginia (SCHEV) concluded that there was a need to distribute graduate engineering education via television from five universities to numerous locations around the Commonwealth so that working engineers could attend advanced courses to improve their job skills, and eventually earn master's degrees. The state council created the Commonwealth Graduate Engineering Program (CGEP) with a consortium of five universities that had graduate engineering programs: VT, UVA, George Mason University (GMU), Old Dominion University (ODU) and Virginia Commonwealth University (VCU). Over the years, Virginia Tech and the University of Virginia have provided the vast majority of courses taught via television under the CGEP banner. The Virginia General Assembly voted a line item into the State budget that provided $6M annually to support the CGEP, with the expectation that some of this money would be returned in the form of tuition payments by students enrolled in the program. Initially, the CGEP consortium decided that the televised courses would concentrate in the areas of Electrical and Computer Engineering (ECE), Civil and Environmental Engineering (CEE), and Industrial and Systems Engineering (ISE). [2]

Distribution of Classes using Satellite Communications and Fiber Optics

Distribution of CGEP televised classes began in 1985 using full transponder bandwidth C-band analog FM satellite communication links, very similar to those used for distribution of cable TV programming, with uplink transmitting facilities in Blacksburg (VT) and Charlottesville (UVA). A return audio link was provided from each of the

[1] Professor of Electrical and Computer Engineering, Virginia Tech, Blacksburg, VA 24061 USA. E-mail: tipratt@vt.edu

classrooms around the Commonwealth. The two universities transmitted a total of 36 hours of graduate engineering classes each week. In 1985, CGEP was able to lease C-band transponder time for $200 per hour. Over the following ten years, the cost for C-band transponders increased to $750 per hour, and the distribution system changed over to compressed and encrypted Ku-band transmission. That allowed five or six video signals to share a single transponder, greatly reducing the transmission costs. However, the quality of the televised material at the receiving sites was degraded because this was the early days of video compression and the compression process was much less sophisticated than today.

One advantage of C-band satellite distribution was that the satellites provided coverage of all of North America and delivered un-encrypted signals, allowing anyone with access to a home satellite TV system to receive the classes. Students on travel could watch classes anywhere in the US, and interested individuals from Venezuela to Alaska could watch the programming, although without access to the return audio link. For the instructor, it meant that the class might be observed by an unknown number of people beyond the intended audience, requiring better preparation and more care with presentation than needed for a closed classroom class. When the distribution system changed to encrypted Ku-band satellite transmission, ease of access was lost. Ku-band satellite transmissions are subject to outages when heavy rain occurs in the slant path between the satellite and earth, but this happened surprisingly infrequently. The reliability of the satellite distribution systems proved to be very high, and rarely was contact lost with a distant site. Backup video tapes were made at the originating and receiving classrooms as a precaution, and also to provide an opportunity for students who missed a class to catch up, or to watch the class again at a later date.

In 1999, the distribution system changed to a dedicated fiber optic network that reached a more limited number of locations, but which provided two way video and audio links. The system was further upgraded in 2006 to use the H.323 full motion digital video standard via the Internet using Asynchronous Transfer Mode (ATM). Improved video compression equipment was installed providing full motion video conferencing capability. [4] The use of ATM over the Internet allows connection to any site, worldwide, and the distance learning network now serves many more users than the CGEP. In Spring 2006, Virginia Tech offered 68 courses through its video conferencing system to a total of 30 different locations, with an enrollment of approximately 1000 students. [3] A connection was provided to the Arab Institute of Science and Technology in Cairo, Egypt, as part of a collaborative international Ph. D. program. A separate data link using H.239 was also added to allow the instructor's computer screen or document writer output to be displayed in each distant classroom. This is of great help when equations need to be displayed, since the resolution of the data connection screen is better than for compressed video. Large plasma and LCD displays with SVGA resolution are now available that provide much better readability for computer generated graphics. Video compression is a lossy process, so some detail is lost when a compressed video signal is displayed. A NTSC television receiver screen has a much lower resolution than an SGVA screen, especially for color signals; when PowerPoint slides are displayed using an NTSC monitor, a large font must be used to ensure readability. This limits the number of characters that can be displayed on a single line – a difficulty when lengthy equations need to be discussed.

For the past four years, Virginia Tech has been creating streaming video files for most of its CGEP classes. Students enrolled in the class can access a university web site and view the class at a convenient time and location. This has proved to be very valuable to students who are located a long distance from a classroom where live TV classes are delivered, or who are sent on travel by their employer. Students can access the streaming video of their class from anywhere in the world, provided they have access to an Internet terminal operating at 128 kbs or higher speed. [1]

THE ECE TELEVISED GRADUATE PROGRAM AT VIRGINIA TECH

The Electrical Engineering Department at Virginia Tech (later ECE) decided to concentrate its CGEP courses into two specific areas: Computer Engineering and Communications. The decision to offer only these two topics was based on the perceived needs of electrical engineers working in Northern Virginia and in military establishments such as NSWC. The ECE related industries in Northern Virginia fall into two groups – telecommunications and defense contractors, with very little manufacturing industry.

Enrollments in ECE classes have varied over the years with the peak period being in the mid-1990s when Virginia's high tech industries were booming. Some computer area courses would enroll 120 students, presenting a serious challenge to the instructor who was provided with very little graduate assistant help. Within the Commonwealth of

Virginia's universities, at that time, there seemed to be a complete disconnect between the number of students enrolled in a class and funding provided to support the teaching mission. In the communications area, enrollments reached a high of 75 in a radar systems course taught by the author in the mid 1990s. After the dot.com bubble burst in 2001, enrollments dropped and now average around 25 per class. Nevertheless, this is large for a graduate class, and the ECE department consistently has some of the largest graduate classes on the Virginia Tech campus.

With the advent of fiber optic transmission via the Internet it became possible to increase the number of classes that were televised. The ECE department now teaches an average of seven televised graduate classes each semester, and has expanded the program to include power systems and electromagnetics.

Working Graduate Students

The separation of instructor and students through an electronic medium makes learning more difficult for the students and teaching more difficult for the instructor. However, the Commonwealth of Virginia is spending tax payers' money to support the CGEP, students enroll in the classes, and instructors are allocated to teach them. The challenge is to make teaching via television an effective tool in the education of graduate students. This requires more effort on the part of the instructor to prepare materials for use in a televised class compared to a class taught in a conventional classroom setting.

The students enrolled at the distant locations are significantly different from the average graduate student in a typical on-campus MSEE program. They are older, sometimes in their fifties, may have been away from the classroom for many years, usually have full time jobs that demand 50 or more hours of their time every week, and are frequently out of town traveling for their employer. They are also more dedicated to their objective of learning a new subject or earning a master's degree, and often out-perform the younger group of full time on-campus students. They do not have the time to complete lengthy assignments, and need flexibility with deadlines to accommodate their other commitments. Unlike full time graduate students who will devote whatever time it takes to complete a difficult assignment, working graduate students will send in an incomplete paper because they simply do not have the time to complete very lengthy assignments. Care is needed in setting challenging assignments that do not require excessively lengthy solutions.

Teaching the Camera

Virginia Tech has created a large number of classrooms for televised classes. The classrooms are equipped with two TV screens, one showing the instructor and the other showing a computer screen, usually PowerPoint slides or the output of a document camera. There are two TV cameras in each classroom, one looking at the instructor and the other at the students. A control panel at the instructor's desk allows the instructor to select which camera or data stream is broadcast. Thus the instructor becomes director, presenter, and camera operator for his or her own TV show.

The number of students in the author's classes is usually evenly divided between an on-campus group and students at distant locations. However, it is important not to concentrate on teaching the students in the classroom, but rather to teach the camera. If all the teaching is directed at the students in front of the instructor, students at a distance become disengaged spectators, watching a class at some remote location. Teaching the camera results in the students who are watching a TV screen feeling much more part of the class, and more engaged in the learning process. This is how announcers on television make you feel that they are talking to you. They usually have a teleprompter right in front of the camera to force them to look at it. Eventually, teaching the camera becomes second nature, and it is then possible to teach an entire class to a TV camera so that it can be recorded and transmitted later.

Communicating with Students

When CGEP first started distributing televised graduate classes via satellite, the Internet was in its infancy and the telephone was the main form of distance communication. Class notes and assignments had to be mailed to distant locations a week in advance of each class. In the 1990s, e-mail developed as the main form of communication, and Blackboard became the method of choice for distributing class notes and assignments. Although Blackboard has a digital drop box, most students prefer to write their work for submission as hard copy, and then mail their papers via courier or snail mail, or scan it into pdf file form for electronic transmission. Writing mathematics on a PC remains a tedious task, despite the existence of specialized software for this purpose. The delays inherent in mailing papers make adherence to strict schedules impossible as it may take more than a week to gather in all the submissions, and just as long to return graded papers to distant locations.

Effective Television Teaching

The chalk board has long been a favorite means of communication between instructors and their students. It is particularly effective as a means of reinforcing important points in a lecture and for writing out equations as part of derivations or explanations. Students who take notes must read what is on the chalk board and then write down some or all of the material. The process of reading and writing undoubtedly contributes to understanding and retention of the subject matter. Usually, instructors write clearly enough that all students in the class can successfully read from the chalk board. However, when teaching via television the chalk board is a poor choice because it lacks the contrast needed for good reproduction at distant locations. The result may be complete loss of communication between the instructor and student, as illustrated in the following section.

A recent trend in much university teaching has been to prepare material in advance on a laptop computer as a sequence of PowerPoint slides that can be projected on a screen in the classroom. PowerPoint is an excellent medium for presenting material via television, but has its dangers both in a regular classroom and when used in distance learning. Detailed PowerPoint slides lull the audience into a false sense of understanding (or sleep) and need to be broken up by a change to the chalk board in the classroom, or a switch to the document camera or instructor in a televised class. PowerPoint slides must also be prepared quite differently when intended for viewing on a TV screen rather than on a large projection screen in a classroom. This point is illustrated in more detail in the following section. It is important that instructors teaching classes via television know what equipment is being used at the receiving sites and prepare materials accordingly.

A better alternative to the chalk board for televised classes is a document camera. The document camera transmits an image of whatever is placed below it, from a standard 8 ½” ×11” sheet to a 1” by 1” illustration. Writing notes for the document camera in real time can be successful, but only if the instructor can write large enough. The same problem exists with the blackboard in a classroom, but somehow instructors seem to cope better with chalk than with a pen. Writing too small for the document camera is a common error, resulting in notes that cannot be read. If the audience cannot read what the instructor has written, both the instructor and the students are wasting their time.

One of the difficulties in teaching via television in a network such as the CGEP uses is that the equipment available at each site varies greatly, and sometimes the data links are of poor quality. Some classrooms are equipped with 27 inch TV monitors showing NTSC composite video. Such monitors have notoriously poor definition, especially for vertical red lines because of the narrow bandwidth of the NTSC standard in that part of the visible spectrum. The NTSC chrominance signal bandwidth for red is only 0.5 MHz. The width of a narrow black vertical line on a TV screen will be about one eighth of the width of the same line in red. Compared to a digital monitor with a SVGA screen, NTSC video monitors display very blurred pictures. The instructor needs to know whether any of the classrooms receiving his or her lecture are using NTSC TV receivers as monitors so that materials can be prepared accordingly. The addition of the H.239 digital data channel allows graphic materials to be projected onto a large screen in the classroom and greatly improves readability, especially when detailed equations need to be sent.

Preparing Materials for Televised Classes

This section shows examples of good and poor technique in televised teaching. Most of the illustrations are taken from recorded classes stored as streaming video by the university’s Video Broadcast Services. The background color on PowerPoint slides tends to be changed during the recording process and appears darker in the illustrations than on the screen when transmitted. The poor definition of TV screens, distortion introduced by compression of the digital picture, and transmission over different grades of line can result in serious degradation of the resulting, material when viewed at a distance. In some cases, as illustrated here, effective communication ceases. Guidelines for the preparation of PowerPoint slides that can overcome these difficulties follow the illustrations.

Figure 1 shows a photograph of a streaming video frame in which the instructor wrote on a large chalk board. The low contrast of the white chalk against a black background results in the material being unreadable. Communication via the written word has ceased in this class for the students at distant locations. Unless an exceptionally broad piece of chalk is used and the instructor writes very large, there is little chance that students viewing a monitor or TV screen will be able to read anything. Figure 2 shows a photograph of a streaming video frame from a class transmitted to Virginia Tech from Egypt. In this example, the instructor has prepared materials correctly for the Virginia Tech network, but equipment problems and the long distance of the Internet connection have degraded the quality of the image to illegibility. It is possible to make out the slide heading, which is usually in 36 or 44 point font on PowerPoint slides. If the rest of the material on the slide had been prepared in 44 point font it would have been legible, with the disadvantage that very few words could be fitted on each slide. The only solution in such cases is to distribute the slides to each student in advance using e-mail or Blackboard so that the students are not dependent on the images and can follow a printed version.

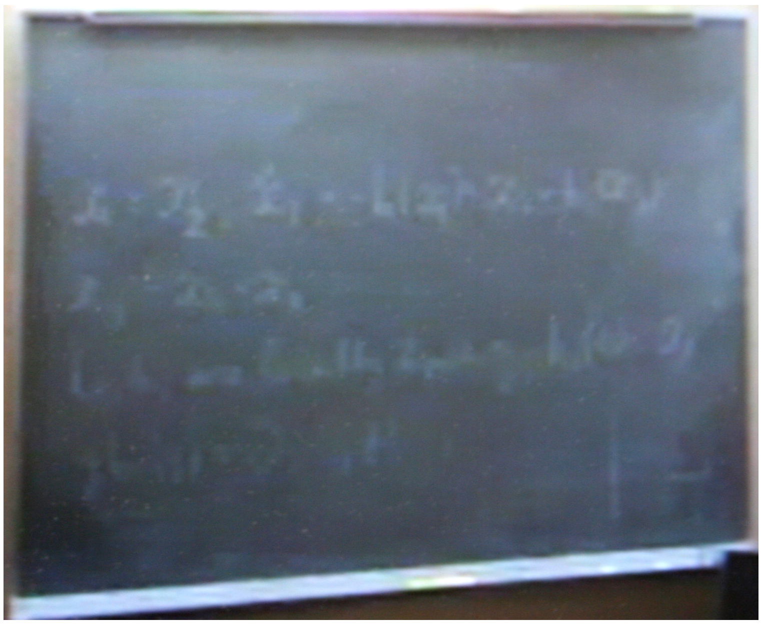


Fig. 1. Example of poor contrast from a chalk board image

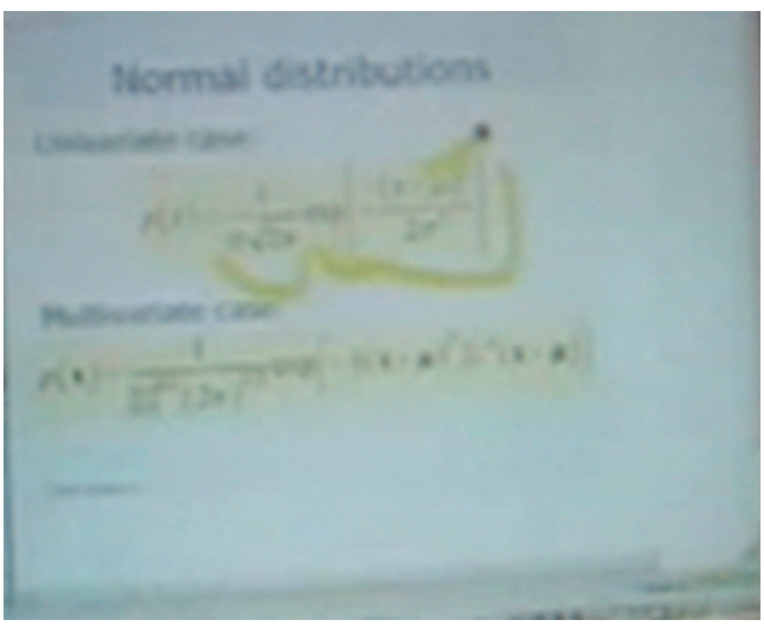


Fig. 2. Poor readability caused by equipment problems and transmission distance

Figure 3 shows a power point slide prepared using 28 point font and bold subscripts and superscripts. The smallest feasible font to use on PowerPoint slides for televised transmission is 28 point when the images are viewed on a NTSC television screen. In a classroom where a student is sitting 20 feet from a 27 inch television set, a regular page of text and equations such as illustrated in Figure 3 has the same size as Figure 3 viewed from a distance of five feet. If the material has become blurred in transmission, as in Figures 5 and 6, even 28 point font can be difficult to read. Because subscripts and superscripts are smaller than regular lettering, the use of bold is essential if they are to be legible after transmission. Backgrounds should be solid pale pastel colors, with blue or gray preferred. Never use white on black or another dark color and avoid backgrounds with detail in them. Compared to Figures 1 and 2, the material in Figure 3 is easy to read and completely legible. The footnote is deliberately kept in 18 point font and is not intended to be readable in a screen image.

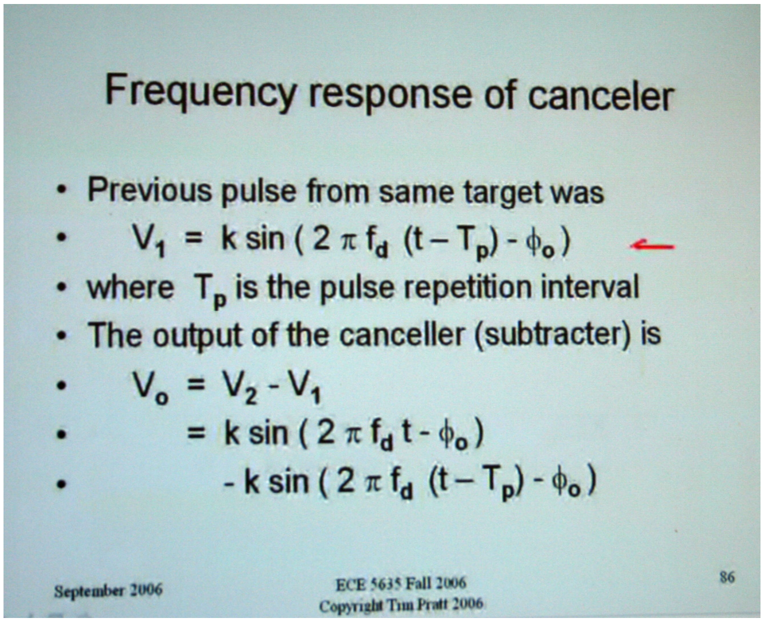
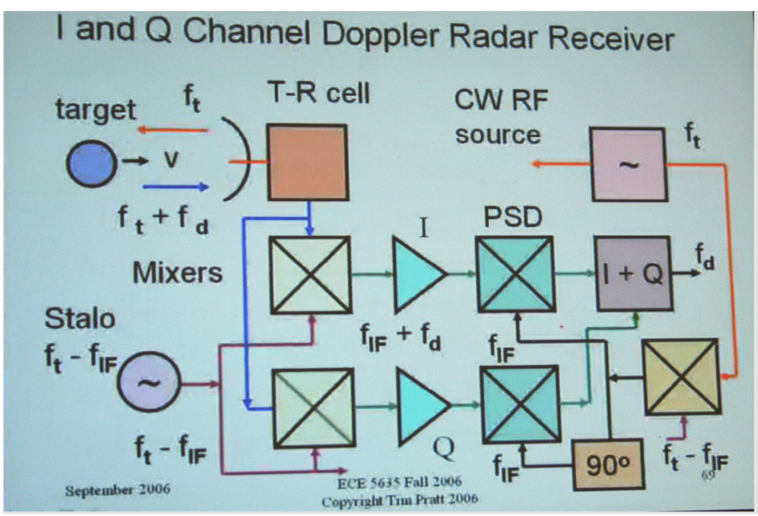


Fig. 3. PowerPoint slide using 28 point font with bold subscripts

Diagrams represent another challenge for instructors teaching systems topics. Figure 4 shows a PowerPoint slide taken from a class on radar systems.



. **Fig. 4.** Example of a PowerPoint slide showing a complex block diagram

Figure 4 shows a simplified diagram of a coherent receiver that can extract Doppler information from the radar returns. In this example pale colors are used to help differentiate the different functions of receiver blocks. This slide has more information than is desirable on a single slide to be viewed on a regular TV screen and omits the later signal processing section of the receiver, but for good understanding by the students needs to show the parallel I and Q channels of the receiver along with the local oscillators.

Teaching material that contains complex mathematics presents one of the major challenges for instructors in electrical engineering. The maximum volume of equations that can be fitted onto a single PowerPoint slide in 28 point font is illustrated in Figure 5. This slide shows the four non-linear simultaneous equations that are solved by every GPS receiver to locate its position. Where equations are larger and longer than in this example they should be sent to students ahead of time by e-mail or posted on Blackboard so that students can print them ahead of class and refer to them at the appropriate time in class. The problem is solved in the Virginia Tech distance learning network at most locations by the direct transmission of the computer output via the H.239 data stream to a large SVGA screen in the distant classroom.

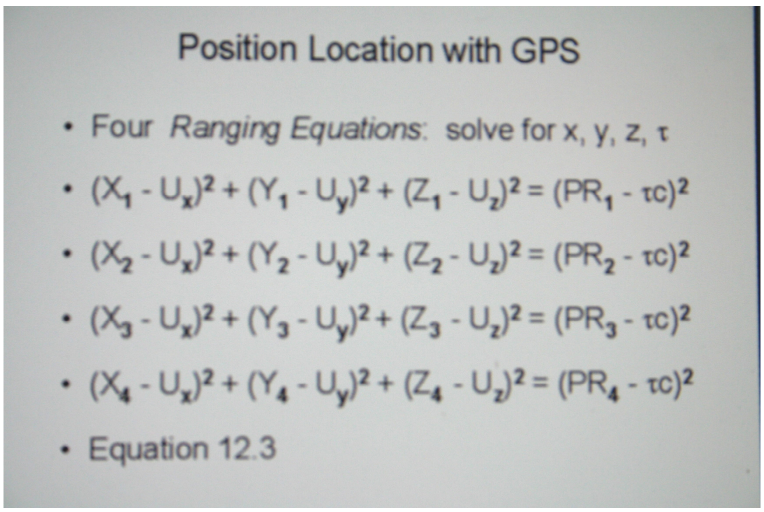


Fig. 5. Example of complicated equations in 28 point font as seen on a NTSC TV screen

Figure 6 shows the same material as Figure 5, but in 24 point font without bold applied to subscripts and superscripts. The loss of readability is clearly seen.

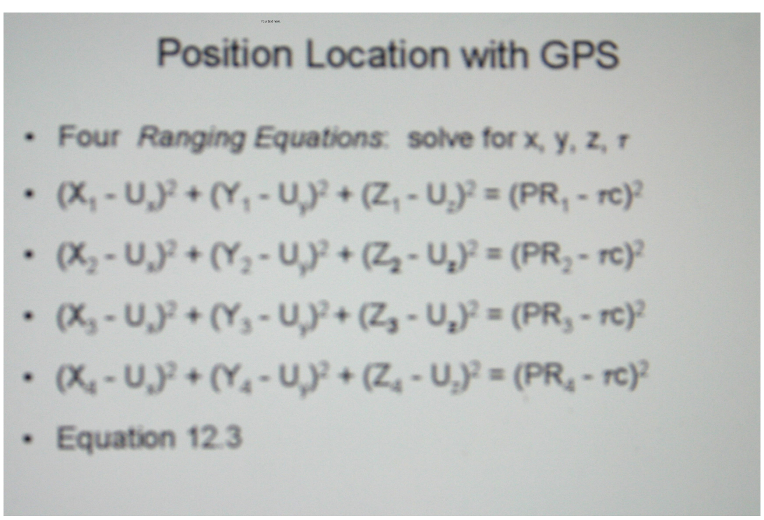


Fig. 6. Same equations as in Figure 5 but using 24 point font without bold.

The document camera makes a good alternative to the chalk board when the answer to a student's question requires a sketch or some mathematics. Figure 7 shows an example taken from streaming video of the same class as Figure 3 and 4. Here the document camera is used with regular size blue paper to discuss a conical scan radar tracking antenna. The lettering below the diagram on the right hand side of the page is too small, which is always a danger when writing in real time.

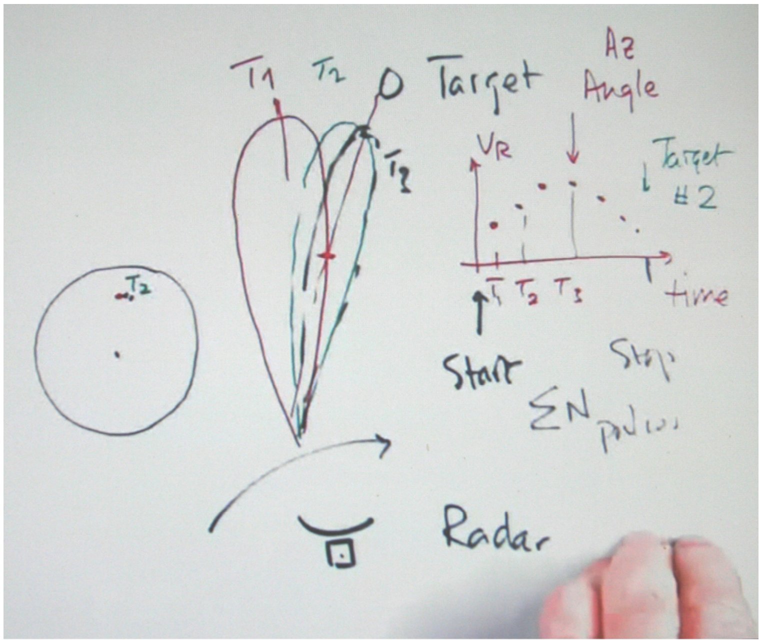


Fig. 7. Example of a sketch for the document camera in answer to a student question.

CONCLUSION

Teaching via television has proved to be a powerful way to extend the benefits of graduate education to a much wider audience than just students on a typical university campus. In the Commonwealth of Virginia this is particularly important because the centers of industry that need graduate engineering courses are hundreds of miles from the tier one universities. Although the infrastructure to support televised teaching is expensive, there are hidden economies in this form of teaching. Full time students on a university campus require space and facilities in which to learn, are not productively employed in an industrial sense and generate no wealth, and frequently are supported from public funds through graduate assistantships. Estimates from the deans' offices at two universities suggest that the true cost of keeping a full time graduate engineering student at a university campus is between $50,000 and $100,000. Most of that expense is saved when the student works full time and takes classes part time.

Effective teaching via television requires careful preparation of graphic material that appears on the screens at distant locations. Conventional television receivers displaying composite video NTSC images have particularly poor resolution. When PowerPoint slides are used the minimum font size that can easily be read on a 27 inch TV screen at a distance of 20 feet is 28 point. The H.239 data channel that has recently been added to the CGEP transmissions has proved valuable in classes that have a high mathematical content, allowing digitally produced graphics to be displayed on a large screen monitor or projected. It is essential that instructors of televised classes know what equipment is in use and also that they get feedback from students at distant locations so that all materials are readable.

ACKNOWLEDGEMENTS

The author wishes to acknowledge the important role of Virginia Tech's Video Broadcast Services group who design, install and manage the video distribution system that supports Virginia Tech's televised education programs throughout the Commonwealth of Virginia and beyond, and in particular Nancy Gibson for her continued help with CGEP televised classes.

REFERENCES

[1] DaSilva, Luiz A. and Scott F. Midkiff, "Leveraging the Web for Synchronous versus Asynchronous Distance Learning," *Proc. Int. Conf. on Engineering Education*, Taipei, Taiwan, 2000.

[2] Scales, Glenda, R., Linda G. Leffell and Cheryl A. Peed, "Distance Learning Trends for Graduate Engineering," *Proc. 2002 ASEE Annual Conference*, ASEE, 2002.

[3] Video Broadcast Services, "Video Conferencing Update – H.323 Conversion, 2006," VBS, Virginia Tech, Blacksburg, VA, 2006.

[4] www.teamsolutions.co.uk/tsstds.html

Timothy Pratt holds B. Sc. and Ph. D. degrees in Electrical Engineering from the University of Birmingham, UK. He is currently a Professor of Electrical and Computer Engineering at Virginia Tech, where he has worked since 1981. He was given the prestigious Virginia Tech Wine Award for Continued Excellence in Teaching in 2004, primarily for his televised teaching. He is a senior member of the IEEE and a member of the IET. His research interests are in satellite communications and position location systems.