Radiowave Propagation
TCOM 690 004 & ECE 699 003

George Mason University

Spring 2012

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Please: by appointment only

1. Announcements

TCOM 690 004 will be joined by ECE 699 003 for the spring 2012 class. We will be meeting as a combined class in Robinson Hall A room 243 almost every Thursday, 7:20 – 10:00 p.m., beginning on February 1st, 2012. The current schedule of classes (see section 11) allows for 14 lectures, with the final exam on Thursday, May 10th, 2012. The exact set of class meeting days is given below in section 11.

2. Expected Background

Some advanced level mathematics above Analytical Geometry will be required, although much of what is presented will build on courses students will have taken in the area of wireless communications, in particular ECE 463 and TCOM 551. Students will be expected to learn, and master, design concepts that require numerical manipulation.

3. Expected Learning Experience

The co-taught courses TCOM 690 004 and ECE 699 003 develop in some detail aspects taught as a single lecture in ECE 463 and TCOM 551 (Digital Communications), and TCOM 607 (satellite communications): namely radiowave propagation. Most students learn hardware and software topics connected with digital communications, but do not have many of the concepts explained to them on what happens between the transmitting antenna and the receiving antenna. Often, this is called the communications *channel* with little explanation as to the physical processes that happen to the electromagnetic signal en route to the receiver. This course will attempt to explain some of these phenomena.

The course will be taught from a satellite-to-ground perspective, but all of the propagation concepts involved are identical to those encountered on terrestrial paths. Atmospheric absorption, rain attenuation, depolarization, etc. occur on horizontal paths and on slant paths through the atmosphere. The two major differences between satellite paths and terrestrial paths – ionospheric impairments and multipath – will be discussed in detail. Some aspects of radar engineering, including UWB radars, will also be part of the course. By the end of the course, students will be thoroughly familiar with all the aspects of radiowave propagation and will be able to apply this knowledge to all forms of wireless communications, whether in distributed wireless networks, WiMAX, LMDS, and mobile communications, in addition to all forms of satellite systems (FSS and VSATs).

The course material will be in PowerPoint slides which, together with homework assignments, will be posted on Blackboard.

NOTE: All communications, in particular homework solution sets, will be distributed to the class through their George Mason University Email accounts. It is therefore essential that students activate their GMU Email accounts. It is a simple matter to have your Email forwarded to a preferred address from the GMU address. **However, please remember you will need to clean out your GMU account regularly so as not to have a storage problem and consequently rejected Emails**. Also, please do **not** use hotmail as a forwarding account, since you will probably not be able to receive Emails with large attachments.

4. Required <u>Books</u> and <u>Calculator</u>

A. Mandatory Textbook

Textbook Title: Satellite-to-Ground Radiowave Propagation, 2nd. edition;

B. Calculator

Students should have a calculator, or a PDA (or equivalent) with a calculator option. The calculator shall have the following functions, as a minimum:

(a) LOG   (This key will convert an entered number into its $\log_{10}$ value)
(b) 10^x (This key will convert the $\log_{10}$ value back into the original number)
(c) SIN   (This key will convert an angle into the sine of that angle)
(d) COS   (This key will convert an angle into the cosine of that angle)
(e) TAN   (This key will convert an angle into the tangent of that angle)
(f) SIN^{-1} (This key will convert the sine value of an angle back into the angle; this action is sometimes called ARCSIN rather than SIN^{-1})
(g) COS^{-1} (This key will convert the cosine value of an angle back into the angle; this action is sometimes called ARCCOS rather than COS^{-1})
(h) TAN^{-1} (This key will convert the tangent value of an angle back into the angle; this action is sometimes called ARCTAN rather than TAN^{-1})

The calculator should also have the normal $+$, $-$, $\times$, $\div$ arithmetical actions.

A number of examples in class will require the conversion from normal numerical values into logarithms (i.e. $\log_{10}$), and vice versa, in addition to using the standard geometrical functions sine, cosine, and tangent.

NOTE: Calculators will be required in the tests and exams. For this reason, advanced calculators that store equations and other processes will not be permitted. Please make sure you have only a simple calculator for the closed book, closed notes tests and final exam. Unusual equations, or long equations, will be given to students in exams in the form of a handout sheet. The key to the exams is being able to understand the processes rather than memorization. A sheet with equations will be available in each test or exam.

5.   Lecture Notes

As noted earlier, Power Point slides for the lectures will be distributed via Blackboard to the class prior to each lecture.

6.   Homework

1. Homework Exercises will be assigned periodically (approximately once per week for the first two-thirds of the course) and are due the following week at the beginning of the class.
2. Homework will be collected in hard copy only, unless there is a specific requirement to provide a 'soft' copy. Homework will be graded. In most questions, what will carry the greatest number of marks will be the process in which the question has been answered, not the answer itself. Please give all intermediate steps in a question so that partial credit may be given, even though you may not have reached the correct solution. And *PLEASE* put your name and ID number on each sheet of paper and staple the sheets together.
3. Homework will not normally be accepted by Email unless prior permission has been given, e.g. a student is on travel.
4. Late homework will only be accepted
   a. With prior permission, and
   b. If the graded homework has not yet been handed back to the class.
5. To help students with travel commitments, one homework may be dropped from the total number of homeworks set. However, the tests draw most of their material from the homeworks set and so students are encouraged to complete all of the homeworks.
6. Solution sets for the homeworks will be available before the tests on those homeworks.

Students are encouraged to work together on homework problems, should they find this advantageous, but they should **only** submit their own written work.

IMPORTANT NOTE

Students are encouraged to find, and use, any and every source they may locate to answer a question or for their term paper. HOWEVER: if elements of their paper have been downloaded from the web or transcribed from another source, STUDENTS MUST WITHOUT FAIL acknowledge the source document. If the elements used are exact copies, those passages must be within quotation marks to note they are not original statements of the student, and the source reference should be adjacent to the text or figure in the body of the work.. This includes duplicated sections, diagrams, and pictures. Failure to acknowledge a source used is considered to contravene the copyright act and may also be subject to honor code proceedings if the student claims the work to be original when it is copied from another person or source. **No more than 20%** of a paper's content may consist of downloaded/quoted material

Available Plagiarism resources may be used to review term papers for plagiarism

7.   Intermediate Tests

Two Tests will be given (in class) during the semester. They will be closed book, closed notes tests of about two hours each. The first test will generally cover class work up to and including the lecture prior to the day of the first test (i.e. lectures 1 through 5 and homeworks 1 through 3). The second test will cover class work that has been done after the first test and up to and including the lecture prior to the day of the second test (i.e. lectures 6 through 10 and homeworks 4 through 6). Tests will be closely based on the homework questions set, and again, it will be the process of calculating the answer that is the most important, not the precise answer obtained. An equation sheet will be available for each test.

8.   Research Paper

Students will be required to submit a research paper on a topic of their choosing that is in the general field of radiowave propagation. The paper should be on the order of 20 pages long (equivalent to about 5000 words on 11×8 paper, plus three or four figures or pictures). What is given below are potential topics a student may choose, but these are by no means exhaustive:

- Radiowave propagation through salt water
- Laser link propagation to submarines from satellites
- Joint impact of the Earth's magnetic field and TEC (Total Electron Content) on the polarization of a linearly polarized wave
- Reliability of large distance site diversity for Earth-space laser communications
- Penetration depth in the lower atmosphere of microwaves transmitted from Earth resources satellites
- Feasibility of tactical laser communications in a battlefield situation (smoke, dust, foliage penetration)
- Propagation considerations for ELF strategic communications links
- Mobile wireless propagation considerations for communications links to NASCAR, and similar, racing vehicles
- Propagation through the topsoil to detect IED weapons or buried artifacts
- UAV-to-satellite optical link considerations
- UAV-to-ground optical link considerations
- Feasibility of *now-casting* for local propagation conditions
- Etc.!!

The research paper is designed to develop the students' awareness of the multifaceted impact of radiowave propagation on our everyday lives. It is also a way of getting students used to writing a detailed technical paper that will almost certainly be required in their work careers. Students may work individually or, **with prior permission**, as pairs on a given project. The research paper shall be written with the following basic formatting and fonts:

Double-spaced lines
Single-sided pages
Times New Roman font
Font size 12

Default MS Word margin spacing.

References cited may be either placed as footnotes on the page where the reference is cited or sequentially in a numbered index at the end. Full references shall be given (all authors, journal name, volume, number, date, pages [start and stop]) and, for web references, the full URL **and the date the material was extracted.**

The research paper will count as the final exam for the course.

9.   Final Exam

As noted above, the research paper will count as the final exam for the course. The research paper will be due by 7:00 p.m. on Thursday, May 10th, 2012. Both a soft copy and a hard copy of the research paper shall be delivered.

10.   Course Grades:

Final Grades will be determined by a weighted average of the homework (the lowest scoring homework being dropped from this calculation), the two tests, and the research paper in the following manner:

      Regular Homework: 15%
      Test 1:   30%
      Test 2:   30%
      Final Exam (research paper):   25%

11.   Course Outline and Book Sections to be Covered

Lecture 1: January 26th, 2012
Radiowave Communications – 1; Some background to early communications satellites: choice of orbit, choice of antenna, choice of frequency, choice of polarization, choice of service; atmospheric properties: atmospheric divisions, weather patterns, rainfall characteristics.
Allnutt, Chapter 1, pp. 1 - 40

Lecture 2: February 2nd, 2012
Radiowave Communications – 2; Precipitation types; raindrop characteristics and distribution: (terminal velocity, drop shapes, drop size distribution); rainfall rate distributions; atmospheric tides; system planning: earth station coordination, site shielding, knife edge diffraction, link budget.
Allnutt, Chapter 1, pp. 40 - 66

Lecture 3: February 9th, 2012

Ionospheric effects; Introduction, some basic formulations, critical frequency, TEC, faraday rotation, delay, ionospheric scintillation, sunspot influence, theory and predictive modeling, system impact.
Allnutt, Chapter 2, pp. 81 - 126

Lecture 4: February 16th, 2012
Clear-Air effects – 1: Refractive effects, reflective effects, multipath, absorptive effects, gaseous attenuation, attenuation in fog, total columnar content.
Allnutt, Chapter 3, pp. 133 - 180

Lecture 5: February 23rd, 2012
Clear-Air effects – 2: Tropospheric scintillation effects – drift measurements, high latitude measurements; spectral analyses, separation of wet and dry components; maritime mobile effects; theory and predictive modeling of clear-air effects, low angle fading, and system impact.
Allnutt, Chapter 3, pp. 180 - 211

Lecture 6: March 1st, 2012
Test No.1
Attenuation effects – 1: Scattering and absorption; power law relationship; effect of drop shapes, size, and temperature; measurement techniques – rain gauges, radiometer, satellite beacon, radars.
Allnutt, Chapter 4, pp. 221 - 268

Lecture 7: March 8th, 2012
Attenuation effects – 2: Experimental results – radiometers, radar, and satellite beacon; variability in space and time, worst month, short-term characteristics, site-to-site variability.
Allnutt, Chapter 4, pp. 269 - 304

Spring Break: March 12th through March 18th

Lecture 8: March 22nd, 2012
Attenuation effects – 3: Correlation of attenuation data – long-term, short-term, correlation between experimental techniques; rain attenuation prediction models – single site, multiple sites; non-geostationary satellite prediction models, site diversity prediction models; system impact.
Allnutt, Chapter 4, pp. 304 - 338

Lecture 9: March 29th, 2012
Depolarization effects – 1: Introduction, basic depolarization considerations – tilt angle and canting angle; cross-polarization discrimination and isolation; measurement

techniques – direct and indirect methods; experimental results, variability in space and time, ice crystal depolarization, canting angles, seasonal and diurnal effects.
Allnutt, Chapter 5, pp. 355 - 395

Lecture 10: April 5th, 2012
Depolarization effects – 2: Worst month, short-term characteristics – duration, intervals, rate-of-change: site-to-site variability; correlation of XPD data – long-term & short-term; correlation of attenuation and depolarization; depolarization prediction models; system impact.
Allnutt, Chapter 5, pp. 395 - 425

Lecture 11: April 12th, 2012
Test No.2
Mobile satellite service propagation effect – 1: Range of propagation parameters; maritime, aeronautical, and land mobile communication services; maritime mobile propagation effects.
Allnutt, Chapter 6, pp. 435 - 461

Lecture 12: April 19th, 2012
Mobile satellite service propagation effect – 1: Aeronautical mobile propagation effects: effect of antenna height; effect of speed; land mobile propagation effects; effect of head absorption; attenuation due to vegetation.
Allnutt, Chapter 6, pp. 461 - 488

Lecture 13: April 26th, 2012
Optical propagation effects: Optical link characteristics; coherence, Frésnel, aperture averaging, and scattering aspects; space-Earth/Earth-space asymmetry; antenna tracking aspects; diffraction limited optics; atmospheric absorption; weather models; optical propagation prediction models; other particulate effects – sand and dust.
Allnutt, Chapter 7, pp. 495 - 536

Lecture 14: May 3rd, 2012
Restoration of performance during signal impairments: ionospheric effects; tropospheric scintillation; atmospheric tides; maritime multipath; rain attenuation; depolarization; interference.
Allnutt, Chapter 8, pp. 541 - 607

Final Exam:
Research papers due by 7:00 p.m., May 10th, 2011