A Course
in
Radar Systems Engineering
Prelude

Dr. Robert M. O'Donnell

IEEE New Hampshire Section
Guest Lecturer

Background

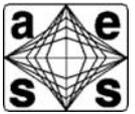- **This course was initially developed in 2000, as an "introductory" course in radar systems engineering for new assistant staff at MIT Lincoln Laboratory and taught by this lecturer for a number of years before retirement in 2008.**

- **Typical profile of student is:**
  - **Recent engineering / physical science graduate from university**
  - **BS degree in Electrical Engineering, Physics, Mathematics, Computer Science / Engineering, or Mechanical Engineering**
  - **Almost all have a solid understanding of Electromagnetism, Probability, and Calculus through Differential Equations and Vector Calculus**

Course Evolution
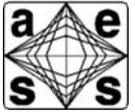
- **The course evolved over the four times that I taught it**
  - **The course, in the form that will be presented, is a further significant evolution of that course**

- **This set of lectures contains material from a very large number of sources**
  - **These are referenced at the end of each section/lecture**
  - **Some of the new topics (not in original course) that will be addressed**
    - **Radar design issues**
    - **Use of radars for remote sensing**
    - **Over the Horizon (OTH) radar**
   - **See course outline for more information**

Who its for and what we are going to do!
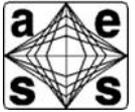
- **Who the course is for**
  - Those with little or no previous knowledge of radar systems

- **What we are going to accomplish**
  - Give participants a start; a broad but not complete, understanding of radar systems issue and a radar's subsystems
  - Example: There are several 500+ page textbooks on just the subject areas of antennas, radar signal processing, or other subsystems

- **Lecture material is reinforced with illustrative problems**
 - Presented at the end of each lecture/section

Textbook
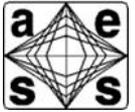
- **Recommended - "Introduction to Radar Systems", Skolnik, 3rd Ed, McGraw Hill**

- **Additional reference textbooks, journal articles, etc. are listed at the end of each lecture/section**

- **For your information:**
  - **Websites of the 50 top University EE/ECE Departments (US News 2007 rankings) were examined:**
  - **Of the fifty, ten offer a "Radar Systems" or "Radar and Remote Sensing" Course**
  - **Textbooks used**
    - **5 – "Introduction to Radar Systems", Skolnik, 3rd Ed, McGraw Hill**
    - **1 – "Radar Principles", Levanon, Wiley**
    - **1 – No text, …. Class notes and journal articles**
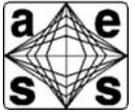   - **3 – No textbook information available from web site**

Course Outline – Core Sections
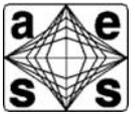
- **Introduction**

- **Reviews of Electromagnetism**

- **Review of Signals and Systems, and Digital Signal Processing**

- **The Radar Equation**

- **Atmospheric Propagation Effects**

- **Detection of Signals in Noise**

- **Radar Cross Section**

- **Antennas – (Two Parts)**

- **Radar Clutter**

Course Outline – Core Sections

- **Radar Waveforms & Pulse Compression Techniques**

- **Clutter Rejection Techniques – Basics and MTI (Moving Target Indication)**

- **Clutter Rejection Techniques – Pulse Doppler Processing**

- **Airborne Pulse Doppler Radar**

- **Radar Observable Estimation and Tracking- Parts 1 and 2**

- **Transmitters and Receivers**

- **Adaptive Processing**

- **Synthetic Aperture Radar (SAR) Techniques**

Course Outline – Additional Material
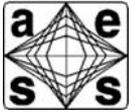
- **Electronic Counter Measures (ECM)**
- **Radar Design Considerations**
- **Radar Open Systems Architecture (ROSA)**
- **Inverse Synthetic Aperture Radar (ISAR) Techniques**
- **Over-the-Horizon Radars**
- **Weather Radars**
- **Space Based Remote Sensing Radars**
- **Air Traffic Control, Civil, and Marine Radars**
- **Ground Penetration Radars**
- **Range Instrumentation Radars**
- **Military Radar Systems**

The total length of each topic will vary from about 30 minutes to up to possibly ~2 hours; Most will be at least an hour. The video stream for most topics will be broken up into a number of "easily digestible" pieces, each 20-30 minutes in length.

Use of Course for Academic Credit
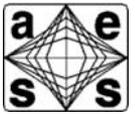
- **The course is being designed to be a senior / 1st year graduate course in Radar Systems**

- **Interested students, whose university does not teach or regularly teach a Radar Systems course may wish ask their faculty advisor for the name of a faculty member who could over see their:**
  - **Choosing the appropriate lectures, or pieces, for a custom 1 or 2 term course sequence**
  - **Correct the assigned problems / or assign others**
    - **Problem solution book is available to faculty from the publisher**
  - **Develop a final examination or term paper project for the course**
    - **A number of suggested term papers are suggested by Dr. Skolnik at the end of the problem solutions book**

- **We to develop a methodology for students to take the course for transferable university credit via distance learning technology**
 - **Please email me if you are interested at bob.radarman@gmail.com**

Acknowledgement for Material Assistance
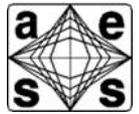
- **MIT Lincoln Laboratory**
  - **Support and encouragement in radar education projects while employed there**

- **The Laboratory has been kind to allow use of a significant number of Lincoln Laboratory copyrighted and previously publicly released viewgraphs and photographic images**
  - **The viewgraphs are a subset (~ 125) from a radar tutorial that Dr. Eric Evans and I had presented at the IEE International Radar Conference in the UK in 2002**
  - **A large number of previously released copyrighted photographic images and viewgraphs from Lincoln Laboratory, books, journals, and other sources**
    - **The above noted MIT LL images and viewgraphs are noted at the bottom of the of the viewgraph**
      - **"Courtesy of MIT Lincoln Laboratory, Used with permission"**
  - **Permission to reuse any of the copyrighted material in these viewgraphs and / or images, or other copyrighted material in the course, must be obtained from the appropriate copyright holder**
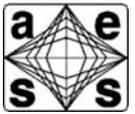
Acknowledgements - Continued
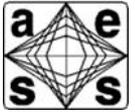
- **IEEE Aerospace and Electronic Systems Society – Board of Governors**
  - Support for computer equipment (PC,SW, server, etc.) and the O & M used to generate this course material

- **IEEE eLearning Library**
  - Who will be hosting the course, at no cost, on that website
  - Steve Welch and Jill Bagley of the IEEE Staff

- **IEEE New Hampshire Section**
  - General Sponsorship and election as chairman of the Education Committee of the NH Section

- **The Computer Science Department of the University of New Hampshire**
  - Who are hosting the course, at no cost, on their website
 - Scott Valcourt of the UNH IT Department for webware support

- **A number of major radar contractors have kindly allowed the use of a significant number of photographic images of their products. Among them :**
    - **The Raytheon Company**
    - **Northrop Grumman Corp.**
    - **Lockheed Martin Corp.**
    - **Boeing Corp.**

- **All copyrighted images are acknowledged by "Courtesy of XYZ Corp. Used with permission"**
    - **"Public Domain" images are acknowledged, but without "Used with permission"**

- **A diligent effort was made not to use any copyrighted images without the owners consent**
    - **A significant number of previously published line drawings were artistically "re-rendered / redrawn" using Adobe Illustrator so as to not infringe upon copyrights**

Copyright Issues
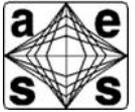
- **Except for copyrighted material, acknowledged in the lectures and reference material, these viewgraphs and the video material, which constitute this course are copyrighted by the Robert M. O'Donnell under Creative Commons Attribution-Noncommercial-Share Alike 3.0 United States License**
  - **Any use of this copyrighted material must be attributed to the author "RMOD Radar Systems"**
  - **None of it may be used for commercial purposes**
  - **It may be shared and modified freely, subject to the above restrictions**
  - **See the following url for more information on the Creative Commons License   http://creativecommons.org/**

- **For any copyright infringement concerns, please contact the author / lecturer Robert O'Donnell at bob.radarman@gmail.com and they will be dealt with promptly**

Author's Note
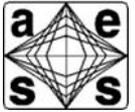
- **As of December 10, 2010, ~1150 viewgraphs which constitute about 90% of the core material have been finished and reviewed by the author**
  - **Colleagues in the radar field have reviewed the viewgraphs before video recording the lectures**

- **I will review and edit the video lectures before publishing them on the web**

- **Even with this process, expect a few technical and typographical errors to leak through this review process and end up being launched on the web**

- **I hope the viewership will be understanding and communicate to me any and all errors so that they can be fixed through appropriate video editing, rerecording, etc.**
  - **All constructive criticism is heartily requested and should be sent to me at bob.radarman@gmail.com**

Dedication
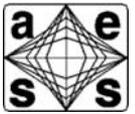
- **To my father, Michael, a lifelong educator, and to my sons and daughter Michael, Meghan, Brian, and Andrew**

- **To wife, Janice, for her patience, understanding, love**

- **To those whose dedication and special gift for the teaching of physical sciences and engineering nurtured and influenced me in my early career:**
  - **Sr. Mary Seraphine, CSJ, St. Mary's High School, Lynn, MA**
  - **Prof. Hans Mark, MIT**
  - **Prof. David Frisch, MIT**
  - **Prof. Herman Feshbach, MIT**
  - **Prof. Walter Selove, University of Pennsylvania**
  - **Prof. Henry Primakoff, University of Pennsylvania**
  - **Prof. Herbert Callen, University of Pennsylvania**
  - **Dr J. David R. Kramer, The MITRE Corp.**
  - **Mr. Charles E. Muehe, MIT Lincoln Laboratory**

- **To Bill Delaney and Dave Briggs for their decades of guidance and mentoring during my career at MIT Lincoln Laboratory**

Special Dedication
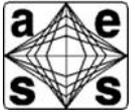
- **In Memory of Roger W. Sudbury**
    - **Friend and mentor**
    - **IEEE Fellow**
    - **MIT Lincoln Laboratory employee**
        - **From Technical Staff to Executive Officer**
    - **Former president of IEEE Microwave Theory and Techniques Society**
    - **Officer and member of MTT Society and many other national IEEE offices and committees**

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