CURRICULUM OF
MS IN AVIONICS ENGINEERING

College of Aeronautical Engineering

National University of Sciences and Technology
Permanent Faculty: Avionics Engineering Department

- Dr Suhail Akhtar  Avionics Engineering
- Dr Azhar Hasan   Avionics Engineering
- Dr Irteza Ali Khan Avionics Engineering
- Dr Manzar Abbas  Avionics Engineering
- Dr Manzar Abbas  Avionics Engineering
- Dr Shoaib Arif    Avionics Engineering
- Dr Zaheer-ud-din Babar Avionics Engineering
- Dr Noman Javed    Avionics Engineering
- Dr Athar Kharal   Mathematics
Contents

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INTRODUCTION

Since its inception in 1965, over the last 50 years, College of Aeronautical Engineering (CAE) has developed itself into a premier institute for imparting both undergraduate and post graduate education in the field of Aeronautical Engineering. During the last 21 years, under the auspicious umbrella of NUST, the College has progressed immensely in terms of faculty development, infrastructure and upgradation of laboratories and IT facilities. The college is not only producing qualified engineers for Pakistan and a number of friendly countries, but had also graduated eight MS courses from 1997 to 2006 in the disciplines of Aerospace Engineering and Avionics Engineering.

MISSION

To produce graduate and qualified researchers in Avionics Engineering discipline to fulfill the requirements of Aeronautical Engineering sector in the country.

OBJECTIVES

The educational objectives of the program in Avionics Engineering are to produce graduates:-

- Who are employable with adequate knowledge and competency in Avionics Engineering.

- Who demonstrate the capacity to assume social, environmental and ethical responsibility in the national and global perspective.

- Who have capability to be effective team members and take a leadership role in research, design, innovation, implementation and operation of Avionics systems and equipment.

- Who can communicate effectively and possesses an enduring desire to continuously enhance their knowledge through life-long learning.

ELIGIBILITY CRITERIA

- Sixteen years of schooling or 4 years (minimum 124 credit hours) education after HSSC / A-Level in relevant discipline (Electrical, Computer, Avionics Engineering or closely relevant discipline)

- Minimum GPA of 2.00

- At least 50% marks in GAT (General) conducted by NTS or GRE general conducted by ETS USA with 650/800 or 151/170 in Quantitative, 400/800 or 146/170 in Verbal and 3.5/6.0 in Analytical.
ASSESSMENT METHODOLOGY

<table>
<thead>
<tr>
<th>Nature of Exam</th>
<th>Duration</th>
<th>Frequency</th>
<th>Weightage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>End Semester Exam</td>
<td>2-3 hours</td>
<td>1</td>
<td>40-50</td>
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<tr>
<td>One Hour Tests</td>
<td>1 hour</td>
<td>1 credit hr course: min 1 OHT 2-4 cr hr course: min 2 OHTs</td>
<td>30-40</td>
</tr>
<tr>
<td>Quizzes</td>
<td>10 min generally</td>
<td>1 cr hr course: min 2 2-4 cr hr course: min 3</td>
<td>10-15</td>
</tr>
<tr>
<td>Assignments</td>
<td>As specified by Professor</td>
<td>As specified by Professor</td>
<td>5-10</td>
</tr>
<tr>
<td>Projects</td>
<td>As specified by Professor</td>
<td>As specified by Professor</td>
<td>10-20</td>
</tr>
<tr>
<td>Lab Work / Projects</td>
<td>3 contact hours</td>
<td>1 per week for each lab cr hr</td>
<td>70-80 of lab cr hr</td>
</tr>
</tbody>
</table>

GRADING SCHEME

<table>
<thead>
<tr>
<th>Letter Grade</th>
<th>Grade Point</th>
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</thead>
<tbody>
<tr>
<td>A</td>
<td>4.00</td>
</tr>
<tr>
<td>B+</td>
<td>3.50</td>
</tr>
<tr>
<td>B</td>
<td>3.00</td>
</tr>
<tr>
<td>C+</td>
<td>2.50</td>
</tr>
<tr>
<td>C</td>
<td>2.00</td>
</tr>
<tr>
<td>F</td>
<td>0.00</td>
</tr>
<tr>
<td>I</td>
<td>Incomplete</td>
</tr>
<tr>
<td>W</td>
<td>Withdrawn/Dropped</td>
</tr>
</tbody>
</table>

STRUCTURE OF MS PROGRAM

<table>
<thead>
<tr>
<th>Courses</th>
<th>Credit Hours</th>
<th>GPA/Non GPA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Core</td>
<td>9</td>
<td>GPA</td>
</tr>
<tr>
<td>Electives</td>
<td>15</td>
<td>GPA</td>
</tr>
<tr>
<td>Additional</td>
<td>2 (RM-898)</td>
<td>Non-GPA</td>
</tr>
<tr>
<td>Thesis</td>
<td>6</td>
<td>GPA</td>
</tr>
<tr>
<td>Total</td>
<td>30+2</td>
<td>30 GPA + 2 NON-GPA</td>
</tr>
</tbody>
</table>
# COURSES: MS IN AVIONICS ENGINEERING

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Title</th>
<th>Credit Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Core Courses (Minimum 3 required)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AV-714</td>
<td>Flight Dynamics and Control</td>
<td>3</td>
</tr>
<tr>
<td>AV-721</td>
<td>Radar Signal Processing</td>
<td>3</td>
</tr>
<tr>
<td>AV-743</td>
<td>Microwave Engineering</td>
<td>3</td>
</tr>
<tr>
<td>MA-844</td>
<td>Advanced Engineering Math</td>
<td>3</td>
</tr>
<tr>
<td><strong>Electives (5 Courses are required)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AV-601</td>
<td>Random Processes</td>
<td>3</td>
</tr>
<tr>
<td>AV-610</td>
<td>Linear Systems</td>
<td>3</td>
</tr>
<tr>
<td>AV-712</td>
<td>Optimal Control</td>
<td>3</td>
</tr>
<tr>
<td>AV-716</td>
<td>Non-linear Control</td>
<td>3</td>
</tr>
<tr>
<td>AV-719</td>
<td>Neural Networks</td>
<td>3</td>
</tr>
<tr>
<td>AV-736</td>
<td>Optimization</td>
<td>3</td>
</tr>
<tr>
<td>AV-739</td>
<td>Introduction to Chaos</td>
<td>3</td>
</tr>
<tr>
<td>AV-741</td>
<td>Electromagnetic Waves and Propagation</td>
<td>3</td>
</tr>
<tr>
<td>AV-818</td>
<td>Aircraft System Identification</td>
<td>3</td>
</tr>
<tr>
<td>AV-820</td>
<td>Detection and Estimation</td>
<td>3</td>
</tr>
<tr>
<td>AV-823</td>
<td>Statistical Learning for Signal Processing</td>
<td>3</td>
</tr>
<tr>
<td>AV-824</td>
<td>Target Detection in Aerial Imagery</td>
<td>3</td>
</tr>
<tr>
<td>AV-825</td>
<td>Spatial Array Processing</td>
<td>3</td>
</tr>
<tr>
<td>AV-829</td>
<td>Information Theory</td>
<td>3</td>
</tr>
<tr>
<td>AV-840</td>
<td>Computational Electromagnetics</td>
<td>3</td>
</tr>
<tr>
<td>AV-841</td>
<td>Advanced Antenna Engineering</td>
<td>3</td>
</tr>
<tr>
<td>AV-845</td>
<td>RF MEMS for Modern Communication Systems</td>
<td>3</td>
</tr>
<tr>
<td>AV-921</td>
<td>Advanced Topic in Signal Processing</td>
<td>3</td>
</tr>
<tr>
<td>AV-931</td>
<td>Advanced Topics in Microwave Engg</td>
<td>3</td>
</tr>
<tr>
<td><strong>Additional Course</strong></td>
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<td></td>
</tr>
<tr>
<td>RM 898</td>
<td>Research Methodology</td>
<td>2</td>
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**TYPICAL SCHEME OF STUDIES**

**OPTION 1 (Microwave Stream)**

<table>
<thead>
<tr>
<th>1st Semester</th>
<th>2nd Semester</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electromagnetic Waves and Propagation</td>
<td>Computational Electromagnetics</td>
</tr>
<tr>
<td>Microwave Engineering</td>
<td>Optimization</td>
</tr>
<tr>
<td>Radar Signal Processing</td>
<td>Neural Networks</td>
</tr>
<tr>
<td>Advanced Engineering Math</td>
<td>Advanced topic in Microwave Engg</td>
</tr>
</tbody>
</table>

**OPTION 2 (Signal Processing Stream)**

<table>
<thead>
<tr>
<th>1st Semester</th>
<th>2nd Semester</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radar Signal Processing</td>
<td>Neural Networks</td>
</tr>
<tr>
<td>Random Processes</td>
<td>Detection and Estimation</td>
</tr>
<tr>
<td>Electromagnetic Waves and Propagation</td>
<td>Microwave Engineering</td>
</tr>
<tr>
<td>Advanced Engineering Mathematics</td>
<td>Advanced Topics in Signal Processing</td>
</tr>
</tbody>
</table>

**OPTION 3 (Controls Stream)**

<table>
<thead>
<tr>
<th>1st Semester</th>
<th>2nd Semester</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linear Systems</td>
<td>Non-linear Control</td>
</tr>
<tr>
<td>Random Processes</td>
<td>Aircraft System Identification</td>
</tr>
<tr>
<td>Radar Signal Processing</td>
<td>Optimization</td>
</tr>
<tr>
<td>Advanced Engineering Mathematics</td>
<td>Flight Dynamics and Control</td>
</tr>
</tbody>
</table>

**Notes:**

- RM-898 Research Methodology will be taught in 3rd Semester to all specialty streams.
- AE-899 Master Thesis Research will be done in 3rd and subsequent semesters for all specialty streams
COURSE DESCRIPTIONS

AV-714 Flight Dynamics and Control

Credit Hours: 3
Pre-requisites: Graduate Standing

Courses Objectives

The course covers following topics. Static stability and trim; stability derivatives and characteristic longitudinal and lateral-directional motions; and physical effects of the wing, fuselage, and tail on aircraft motion. Flight vehicle stabilization by classical and modern control techniques; time and frequency domain analysis of control system performance; and human-pilot models and pilot-in-the-loop controls with applications. Parameter sensitivity; and handling quality analysis of aircraft through variable flight conditions. Introduction to nonlinear flight regimes.

Course Contents:

- Vector Kinematics
- Quaternion and Matrix Analysis of Kinematics
- Geodesy & Rigid Body Dynamics
- Review of Aerodynamics
- Static Stability Analysis
- Review of Classical and Modern Control Theory
- Nonlinear Aircraft Model
- Linear Models and Stability Derivatives
- Simulation of Aircraft Dynamics
- Trim point Calculations & Numerical Linearization
- Aircraft Rigid Body Modes
- Handling Qualities
- Stability Augmentation
- Control Augmentation
- Autopilots
- Review

Course Outcomes:

- To develop state space and transfer function models of physical systems
- To simulate nonlinear systems
- To linearize nonlinear systems
- To analyze a system for stability
- To design a feedback controller to meet stability and performance requirements
- To analyze a flight vehicle for trim conditions, stability and handling qualities

Recommended Reading (Including Textbooks and Reference Books)

- Airplane Flight Dynamics & Automatic Controls by Jan Roshkam
- Aircraft Control & Simulation by B.L. Stevens & F. L. Lewis.

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**AV-721 Radar Signal Processing**

Credit Hours: 3

Pre-requisites: Graduate Standing

Courses Objectives:

This course will provide in-depth coverage of fundamental topics in radar signal processing. The list of topics includes target and interference models, matched filtering, waveform design, Doppler processing, and threshold detection and CFAR. In addition, introductions are provided to the advanced topics of synthetic imaging and space-time adaptive array processing.

Course Contents:

- Review of Probability and Random Variables
- Radar Fundamentals
- Signal Models
- Sampling & Quantization
- Waveforms
- Clutter Filtering
  a. MTI
b. Pulse Doppler

- Detection
  a. Basic threshold detection
  b. Automatic (CFAR)

Course Outcomes:

The passing student will be able to:
- Describe operation of radar systems and discuss their main design parameters and components
- Describe signals and waveforms used in radar systems
- Discuss problems and design challenges in radar signaling and waveforms
- Use various tools (or simulators) for signal and system level simulations in radar systems
- Discuss various signal processing techniques for various radar operations including MTI, pulse Doppler and SAR radars

Recommended Reading (Including Textbooks and Reference Books)


AV-743 Microwave Engineering

Credit Hours: 3

Pre-requisites: AV-231: EM Theory or equivalent basic EM course
- AV-332: Transmission Lines and Waveguides or equivalent

Courses Objectives:

This course is focused on the fundamentals of RF engineering. It starts by discussing the basics of RF system-level design particularly for wireless systems. Subsequently, it reviews transmission line fundamentals followed by impedance matching techniques and microwave networks. The course continues by covering design techniques of microwave filters, and RF amplifiers. Noise and interference issues are also introduced. The course also includes special topics like adaptive RF electronics
Course Contents:

- Wireless systems overview
- Transmission line fundamentals
- Impedance matching and the Smith Chart
- Scattering parameters and microwave network
- Noise in microwave systems
- Resonators
- Lumped-element filters
- Distributed filters
- RF Amplifiers
- Special Topic by instructor

Course Outcomes:

After the course the participants should be able to:

- Apply electromagnetic theory to calculations regarding waveguides and transmission lines.
- Describe, analyse and design simple microwave circuits and devices e.g. matching circuits, couplers, antennas and amplifiers.
- Describe and coarsely design common systems such as radar and microwave transmission links.
- Describe common devices such as microwave vacuum tubes, high-speed transistors and ferrite devices.
- Handle microwave equipment and make measurements.

Recommended Reading (Including Textbooks and Reference Books):

- “Microwave and RF Wireless Systems” by D.M. Pozar

MA-844  Advanced Engineering Mathematics

Credit Hours: 3

Pre-Requisites: Nil

Course Objectives

To impart engineering knowledge and to develop problem analysis and solving ability of Advanced Engineering Mathematics for Aerospace Engineering problems.

Course Contents

- Differential Equations
- Matrices as geometrical transformations, Matrix decompositions
Course Outcomes

After studying this course, the graduate will be able to apply the acquired knowledge in various research areas of Advanced Engineering Mathematics in Aerospace Engineering.

Recommended Readings (Text book and References)

- User guide for Maple 2015.

AV-601 Random Processes

Credit Hours: 3

Pre-requisites: Graduate standing

Courses Objectives:

This course will prepare the students to grasp advanced and applied concepts in probability and statistics. Course will cover topics in random variable theory, stochastic processes, correlation and power spectrum, mean-square estimation, filter design, decision theory, Markov processes, simulation, stochastic calculus and optimal systems for filtering and detection.

Course Contents:

- Review of Probability and Random Variables
- Two Random Variables.
- Random Sequences.
- Stationarity.
- Power Spectral Density.
- Response of Linear Systems to Random Inputs.
- Ergodicity.
- Expansions of Random Processes.
- Markov Processes.
- Simulation

**Course Outcomes:**

This course will prepare the students to grasp advanced and applied concepts in probability and statistics.

**Recommended Reading (Including Textbooks and Reference Books)**


**AV-610 Linear Systems**

**Credit Hours:** 3

**Pre-requisites:** Graduate Standing

**Courses Objectives:**


**Course Contents:**

- Introduction
- State space representation of linear systems
- Linear vector Spaces, Bases, Projection operators
- Eigen Values, Eigen Vectors
• Linear Operators, Stability & Solution of linear systems
• Canonical Forms
• Singular Values and their applications
• Controllability, Observability concepts
• Minimum Realization of linear systems
• State Feedback
• Full state and reduced state observers
• Continuous Time LQR
• Discrete-Time LQR
• Continuous -Time LQG
• Discrete-Time LQG
• End Semester Exam

Course Outcomes:

• Detailed knowledge about state space representation of linear time invariant systems in continuous and discrete time
• To formulate specifications and dynamic models as a basis for design of linear control systems and state estimators under influence of noise and disturbances

Recommended Reading (Including Textbooks and Reference Books)

• Fundamentals of Linear State Space Systems by John S. Bay
• Linear System Theory by Chi-Tsong Chen.
  • Control System Design: An Introduction to State-Space Methods by Bernard Friedland

AV-712 Optimal Control

Credit Hours: 3
Pre-requisites: AV-610: Linear Systems

Courses Objectives:

This course studies basic optimization and the principles of optimal control. It considers deterministic and stochastic problems for both discrete and continuous systems. The course covers solution methods including numerical search algorithms, model predictive control, dynamic programming, variational calculus, and approaches based on Pontryagin's maximum principle, and it includes many examples and applications of the theory.
Course Contents:

- Introduction
- Nonlinear optimization
- Nonlinear optimization
- Dynamic programming
- Dynamic programming
- Calculus of variations – general
- Calculus of variations – control
- Calculus of variations – control
- LQR/LQG - stochastic optimization
- LQR/LQG - stochastic optimization
- LQR/LQG - stochastic optimization
- $H_{\infty}$ and robust control
- $H_{\infty}$ and robust control
- On-line optimization and control (MPC)
- On-line optimization and control (MPC)
- End Semester Exam

Course Outcomes:

The students will learn some basic notions and results in control theory, which are very useful for applied mathematicians. They will learn how to use these tools in solving specific problems.

Recommended Reading (Including Textbooks and Reference Books)

- Optimal Control Theory: An Introduction by Donald E. Kirk.
- Non-Linear Programming, by Dimitri P. Bertsekas. 2nd Ed
- Dynamic Optimization by Arthur E. Bryson.

**AV-716 Non-Linear Control**

Credit Hours: 3

Pre-requisites: AV-610 Linear Systems

Courses Objectives:

The course covers the analysis and design of nonlinear systems and nonlinear control systems. Stability analysis using Lyapunov, input-output and asymptotic methods. Design of stabilizing controllers using a variety of methods:
linearization, absolute stability theory, vibrational control, sliding modes and feedback linearization.

Course Contents:

- Phase Portraits
- Equilibrium Points, Limit Cycles
- Bifurcations, Linearization
- Lyapunov Stability
- Invariance Principal Region of Attraction
- Time Varying Systems, Perturbed Systems
- Passivity
- Popov Criteria, Boundedness Ultimate boundedness
- Perturbed Systems, Input to state stability, Input-output stability
- $L_2$ gain, Normal Form, Strict Feedback Forms
- Feedback Linearization
- Back Stepping
- Control Lyapunov Functions, Output feedback
- Sliding mode control
- Nonlinear Observers
- Adaptive Control

Course Outcomes:

- Solve problems using classical methods for analysis of nonlinear dynamical systems, such as linearization and phase-plane analysis, equilibria and oscillations.
- Determine controllability for nonlinear systems.
- Have basic knowledge about optimal control theory, and how to solve standard optimal control problems.

Recommended Reading (Including Textbooks and Reference Books)

- Applied Non-Linear Control by Jean-Jacques E Solotine and Weiping Li
- Non-Linear Systems by Hassan Khalil.
AV-719 Neural Networks

Credit Hours: 3
Pre-requisites: Graduate Standing

Courses Objectives:

This course explores the organization of synaptic connectivity as the basis of neural computation and learning. Perceptrons and dynamical theories of recurrent networks including amplifiers, attractors, and hybrid computation are covered. Additional topics include backpropagation and Hebbian learning, as well as models of perception, motor control, memory, and neural development.

Course Contents:

- Perceptrons: Simple and Multilayer
- Perceptrons as Models of Vision
- Linear Networks
- Lateral Inhibition and Feature Selectivity
- Objectives and Optimization
- Hybrid Analog-Digital Computation, Ring Network
- Constraint Satisfaction, Stereopsis
- Bidirectional Perception
- Signal Reconstruction
- Hamiltonian Dynamics
- Antisymmetric Networks
- Excitatory-Inhibitory Networks Learning
- Associative Memory
- Models of Delay Activity Integrators
- Multistability Clustering
- VQ, PCA
- Delta Rule
- Conditioning, Back-propagation
- Stochastic Gradient Descent
- Reinforcement Learning

Course Outcomes:

- Describe the relation between real brains and simple artificial neural network models.
- Explain and contrast the most common architectures and learning algorithms for MultiLayer Perceptrons, Radial-Basis Function Networks, Committee Machines, and Kohonen Self-Organising Maps.
- Discuss the main factors involved in achieving good learning and generalization performance in neural network systems.
• Identify the main implementational issues for common neural network systems.
• Evaluate the practical considerations in applying neural networks to real classification and regression problems.

Recommended Reading (Including Textbooks and Reference Books)

• Neural Networks for Modeling and Control of Dynamic Systems by M. Norgaard
• Neural Networks for Pattern Recognition by C. M. Bishop
• Handbook of Neural Network Signal Processing, edited by Yu Hen Hu
• Neural Network Design by Martin T. Hagan.

**AV-736 Optimization**

**Credit Hours:** 3

**Pre-Requisites:** Nil

**Course Objectives**
To impart engineering knowledge and to develop problem analysis and solving ability of Multidisciplinary Design Optimization for Avionics Engineering problems.

**Course Contents**
- Basic convexity concepts.
- Convexity and optimization.
- Review of linear and non-linear constrained optimization formulations.
- Scalar versus vector optimization problems from systems engineering and architecting of complex systems.
- Heuristic search methods: simulated annealing, genetic algorithms.
- Sensitivity, tradeoff analysis, goal programming and iso-performance.
- Engineering systems modeling for design and optimization.
- Selection of design variables, objective functions and constraints.
- Overview of principles, methods and tools in multidisciplinary design optimization (MDO) for systems.
- Subsystem identification, development and interface design.
- Multi-objective optimization and Pareto optimality.
- Specific applications from aerospace, industrial and electrical engineering.

**Course Outcomes**
After studying this course, the graduate will be able to apply the acquired knowledge in various research areas of Multidisciplinary Design Optimization in Avionics Engineering.
AV-739 Introduction to Chaos

Credit Hours: 3

Pre-requisites: Graduate Standing

Courses Objectives:

This is a course on bifurcations, chaos, fractals and their applications in diverse fields such as price fluctuations in the stock market, flow of data traffic on the Internet, biological rhythms, and superconducting circuits with particular emphasis on applications in automatic control and telecommunications. The theory is developed systematically, starting with first-order differential equations and their bifurcations, followed by phase plane analysis, limit cycles and their bifurcations, and culminating with the Lorenz equations, chaos, iterated maps, period doubling, renormalization, fractals, and strange attractors.

Course Contents:

- Introduction
- Flows in a line
- Bifurcations
- Flows on Circle
- Phase Plane
- Limit Cycles
- More Bifurcations
Course Outcomes:

- Ability to carry out research of nonlinear dynamical systems using the method of complete bifurcation groups.
- Knowledge of modern research methods for nonlinear dynamical systems.
- Knowledge of general regularity in nonlinear dynamical systems.

Recommended Reading (Including Textbooks and Reference Books)

- Chaos in Automatic Control edited by Wilfrid Perruquetti
- Chaos Applications in Telecommunications edited by Peter Stavroulakis
- Non-linear Dynamics & Chaos by Steven H. Strogatz.

**AV-741 Electromagnetic Waves and Propagation**

Credit Hours: 3

Pre-requisites: AV-231: EM Theory  
MA-604: Advanced Engineering Mathematics

Courses Objectives:

This course is intended to equip the graduate student with the EM fundamentals. The course reviews the general concepts (Maxwell's equations, materials interaction, boundary conditions, energy flow); statics (Laplace's equation, Poisson's equation); distributed parameter systems (classification of solutions, transmission lines, and waveguides); radiation and antennas (arrays, reciprocity, Huygen's principle); a selected special topic for example waves in anisotropic media
Course Contents:
- Electrostatics and dielectric materials
- Magnetostatics and magnetic materials
- Maxwell's equations
- Propagation and reflection of plane waves for different materials
- TE and TM mode, transmission lines and wave guides
- Boundary Value Problems
- Special topic selected by the instructor
- Review and Exams

Course Outcomes:
- To be able to discuss and deduce equations to describe wave propagation,
- To formulate potential concepts to relate wave properties and their excitation.
- To have acquired knowledge of transmission lines for pulsed and sinusoidal steady state excitation;
- To have an understanding of wave interference and resonance on transmission lines;
- To have acquired techniques for the measurement of basic transmission line parameters, such as the reflection coefficient, standing wave ratio, and impedance.
- To have knowledge of, physical interpretation, and ability to apply Maxwell's equations to determine field waves, potential waves, energy and charge conservation conditions. To have some knowledge of antenna arrays and their usefulness to modern wireless applications.

Recommended Reading (Including Textbooks and Reference Books)
- Fields and Waves Electromagnetics, 2nd Edition by K.Cheng
- Electromagnetic Fields, 2nd Editon by Roald K. Wangness
AV-818 Aircraft System Identification

Credit Hours: 3

Pre-requisites: AV-610 Linear Systems
                AV-601 Theory and Random Processes

Courses Objectives:

This course covers the mathematical foundations of System Identification, Non-parametric techniques, Parametrizations and model structures, Parameter estimation, Asymptotic statistical theory, User choices, Experimental design, Choice of model structure, aircraft system identification.

Course Contents:

- Introduction to System ID, Models, Review of linear systems
- Review of probability, random variables, Stochastic processes
- Response of linear systems to random inputs
- Propagation of statistics
- Introduction to Kalman Filtering
- Least Sq Estimation method
- Least Sq Estimation method
- Mid Term, Time domain methods
- Freq. domain methods
- Introduction to PEM
- Regression analysis
- Application of PEM to aircraft system ID
- Experiment design, Maximum Likelihood Estimation methods
- Maximum Likelihood Estimation methods
- Introduction to Subspace methods

Course Outcomes:

The student will be able to:

- Recognize a problem of system identification
- Propose and implement solutions to simple identification problems
- Identify a dynamical systems using input-output data
- Validate a model of system that has been identified, and compare different simple models
- Design an experiment to identify a simple system
- Develop a deeper understanding of system identification by him/herself, if necessary, in order to solve more complex problems
Recommended Reading (Including Textbooks and Reference Books)

- Aircraft System Identification: Theory and practice by Vladislav Klein and Eugene A. Morelli
- System Identification: Theory for the user by L Ljung.

AV-820 Detection and Estimation

Credit Hours: 3

Pre-requisites: AV-601 Random Processes

Courses Objectives:

The objective of this graduate-level course is to provide an in-depth coverage of topics of signal detection and estimation. It will sever to prepare the students to undertake research and development related to statistical signal processing and communications techniques involving detection and estimation.

Course Contents:

- Review of Gaussian variables and processes; problem formulation and objective of signal detection and signal parameter estimation in discrete-time domain.
- Statistical Decision Theory.
- Detection of Deterministic Signals.
- Detection of Random Signals.
- Nonparametric Detection.
- Estimation of Signal Parameters.
- Signal Estimation in Discrete-Time.

Course Outcomes:

The course students will be able to:

- Apply suitable hypothesis testing criteria for signal detection problems
- Use parameter estimation in signal processing and communication problems
- Design a estimator and detector
Recommended Reading (Including Textbooks and Reference Books)


AV-823 Statistical Learning for Signal Processing

Credit Hours: 3

Pre-requisites: Prerequisite: Vector spaces and probability
Graduate Standing

Courses Objectives:

This course discusses the use of machine learning techniques to process signals. A variety of topics are covered from data driven approaches for characterization of signals such as audio including speech, images and video, and machine learning methods for a variety of speech and image processing problems.

Course Contents:

- Overview (3 lectures) Basic concepts of classification and regression, decision rules, generalization, supervised learning, unsupervised learning, Bayes theory, empirical risk minimization
- Nearest-neighbor classification (2 lectures) 1-NN and k-NN classification, variance-bias tradeoff, risk analysis
- Linear discriminant functions (5 lectures) Binary and M-ary classification; learning methods; Support vector Machines
- Basis expansion and regularization (3 lectures)
- Model Assessment and Selection (2 lectures) Model complexity, statistical and information-theoretic metrics, Bayesian approach, crossvalidation
- Neural networks (3 lectures)
- Sparse Methods (4 lectures) Dimensionality reduction, L1 regularization, lasso, group lasso, sparse coding, sparse Principal Components Analysis, low-rank matrix approximation
Graphical Models (4 lectures) Basic models, Bayesian networks, inference on graphs
Active Learning (1 lecture)
Distributed Learning (1 lecture) Collaborative training, distributed algorithms

Course Outcomes:
The student should be able to:

- Explain, describe, and understand the notion of a random process and statistical time series
- Characterize random processes in terms of its statistical properties, including the notion of stationarity and ergodicity
- Define, describe, and understand the notion of the power spectral density of stationary random processes; analyse and manipulate power spectral densities
- Analyse in both time and frequency the affect of transformations and linear systems on random processes, both in terms of the density functions, and statistical moments
- Explain the notion of parametric signal models, and describe common regression-based signal models in terms of its statistical characteristics, and in terms of its affect on random signals
- Apply least squares, maximum-likelihood, and Bayesian estimators to model based signal processing problems

Recommended Reading (Including Textbooks and Reference Books)
- R. Duda, P. Hart, and D. Stork, Pattern Classification, 2nd ed., 2001
- C. Bishop, Pattern Recognition and Machine Learning, 2007

AV-824 Target Detection in Aerial Imagery

Credit Hours: 3
Pre-requisites: Graduate Standing
Courses Objectives:

This course will introduce the student to computer vision algorithms, methods and concepts which will enable the student to implement computer vision systems with emphasis on applications to target detection in aerial imagery. This course will also familiarize the student with a structural analysis of aerial photographs, of suburban areas in particular, which show very complex geographical structures typical hardware as well as software development tools. Students will use the C programming language to implement computer vision algorithms.

Course Contents:

- Overview (3 lectures) Basic concepts of classification and regression, decision rules, generalization, supervised learning, unsupervised learning, Bayes theory, empirical risk minimization
- Nearest-neighbor classification (2 lectures) 1-NN and k-NN classification, variance-bias tradeoff, risk analysis
- Linear discriminant functions (5 lectures) Binary and M-ary classification; learning methods; Support vector Machines
- Basis expansion and regularization (3 lectures)
- Model Assessment and Selection (2 lectures) Model complexity, statistical and information-theoretic metrics, Bayesian approach, crossvalidation
- Neural networks (3 lectures)
- Sparse Methods (4 lectures) Dimensionality reduction, L1 regularization, lasso, group lasso, sparse coding, sparse Principal Components Analysis, low-rank matrix approximation
- Graphical Models (4 lectures) Basic models, Bayesian networks, inference on graphs
- Active Learning (1 lecture)
- Distributed Learning (1 lecture) Collaborative training, distributed algorithms

Course Outcomes

The student should be able to:

- Explain, describe, and understand the notion of a random process and statistical time series
- Characterize random processes in terms of its statistical properties, including the notion of stationarity and ergodicity
- Define, describe, and understand the notion of the power spectral density of stationary random processes; analyse and manipulate power spectral densities
- Analyse in both time and frequency the affect of transformations and linear systems on random processes, both in terms of the density functions, and statistical moments
- Explain the notion of parametric signal models, and describe common regression-based signal models in terms of its statistical characteristics, and in terms of its affect on random signals
• Apply least squares, maximum-likelihood, and Bayesian estimators to model based signal processing problems

Recommended Reading (Including Textbooks and Reference Books)

• R. Duda, P. Hart, and D. Stork, Pattern Classification, 2nd ed., 2001
• T. Hastie, R. Tibshirani, and J. Friedman, The Elements of Statistical Learning, 2nd Ed., Springer, 2009
• C. Bishop, Pattern Recognition and Machine Learning, 2007
• D. McKay, Information Theory, Inference, and Learning Algorithms, 2003

AV-825 Spatial Array Processing

Credit Hours: 3

Pre-requisites: AV-601 Random Processes
                AV-610 Linear Systems

Courses Objectives:

This is the first course in Avionics Engineering MS program that introduces application areas where signals are sampled over space and time. Transfer knowledge of time-based techniques to spatial processing. Develop algorithms unique to spatial processing.

Course Contents:

• Introduction and Sales Pitch
• Propagating Waves
• Wavenumber-Frequency Space
• Apertures, Part I
• Apertures, Part II
• Delay-and-Sum Beamforming for Plane Waves
• Delay-and-Sum Beamforming for Spherical Waves
• Filter-and-Sum Beamforming
• Conventional Narrowband Beamforming
• Stochastic Narrowband Models
• Signal to Noise
• Time Averaging
• Spatial Averaging and Co-arrays
• Constrained Optimization
• MVDR Beamforming
• Subspace Methods: Eigenvalue Method and MUSIC
• Root MUSIC
• ESPRIT
• Robust Constrained Estimation
• Introduction to Estimation Theory
• Maximum-likelihood narrow-band direction finding and the EM algorithm
• "Deterministic Signal" Gaussian Model
• "Stochastic Signal" Gaussian Model
• Introduction to Cramer-Rao Bounds
• Cramer-Rao Bounds for Arrays
• Transformations of Cramer-Rao Bounds

Course Outcomes:

The student will be able to

• Extrapolate the fundamentals of arrays, signal models in various domains
• Distinguish the performance of various types of sensor arrays like ULA’s, Planar and Random arrays.
• Predict the importance of spatial domain analysis under the influence of adverse effects like Aliasing and white noise signaling conditions.
• Interpret the basics and types of beam forming techniques that can be used to obtain effective beam patterns.
• Outline various non-parametric methods and spatial smoothing techniques to effectively solve the Direction of arrival estimation problems.

Recommended Reading (Including Textbooks and Reference Books)


AV-829 Information Theory

Credit Hours: 3
Pre-requisites: Random Processes
Courses Objectives:

The purpose of this course is to introduce the quantitative theory of information and its applications to reliable, efficient communication systems.

Course Contents:

- Introduction, entropy
- Jensen's inequality, data processing theorem, Fanos's inequality
- Different types of convergence, asymptotic equipartition property (AEP), typical set, joint typicality
- Entropies of stochastic processes
- Data compression, Kraft inequality, optimal codes
- Huffman codes
- Shannon-Fano-Elias codes, Slepian-Wolf
- Channel capacity, binary symmetric and erasure channels
- Maximizing capacity, Blahut-Arimoto
- The channel coding theorem
- Strong coding theorem, types of errors
- Strong coding theorem, error exponents
- Fano's inequality and the converse to the coding theorem
- Feedback capacity
- Joint source channel coding
- Differential entropy, maximizing entropy
- Additive Gaussian noise channel
- Gaussian channels: parallel, colored noise, inter-symbol interference
- Gaussian channels with feedback
- Multiple access channels
- Broadcast channels
- Finite state Markov channels
- Channel side information, wide-band channels

Course Outcomes:

- The student will be able to:
  - Understand and apply fundamental concepts in information theory such as probability, entropy, information content and their inter-relationships.
  - Understand the principles of data compression.
  - Compute entropy and mutual information of random variables.
  - Implement and analyse basic coding and compression algorithms.
Understand the relationship of information theoretical principles and Bayesian inference in data modelling and pattern recognition.

Understand some key theorems and inequalities that quantify essential limitations on compression, communication and inference.

Know the basic concepts regarding communications over noisy channels.

Recommended Reading (Including Textbooks and Reference Books)


AV-840 Computational Electromagnetics

Credit Hours: 3

Pre-requisites: AV-231: EM Theory
                   MA-604 : Advanced Engineering Mathematics

Courses Objectives:

The numerical solution of Maxwell's equations is studied. Numerical methods such as the Finite Element Method and the Finite Difference Method are presented for the solution of both differential and integral equations. Applications studied include: waveguides (microstrip, VLSI interconnects, optical, discontinuities), scattering (frequency selective surfaces, arbitrary scatterers), antennas, magnetics, semiconductor devices, and inverse scattering

Course Contents:

- Maxwell's equations,
- Finite difference solution of Maxwell's eqns., wave eqns.
- Variational formulations
- Finite element method - solution of differential equations arising in statics, waveguides, scattering (radiation boundary condition)
- Green's identities and development of integral equations
- Method of Moments
• Spectral domain formulation for microstrip, frequency selective surfaces, printed antennas
• Inverse scattering
• Computer hardware and software issues
• Special topic selected by the instructors

Course Outcomes:
• Learn advanced topics in 3D vector finite element methods for solving Maxwell equations
• Learn advanced topics in fast method, such as FFT-based methods, fast multipole methods, and rank-deficiency based methods, for solving surface integral equation methods
• Introduced to various mechanisms of coupling finite elements to integral equation methods for solving unbounded electromagnetic problems

Recommended Reading (Including Textbooks and Reference Books)


AV-841 Advanced Antenna Engineering

Credit Hours: 3
Pre-requisites: AV-231: EM Theory or equivalent basic EM course
                AV-332: Transmission Lines and Waveguides or equivalent

Courses Objectives:
To study basic and advanced topics of antenna engineering that includes antenna design for the given specifications, antenna measurement techniques, feeding mechanism, arrays and ultra-wideband applications

Course Contents:
• Review of Antenna Basics
• Dipole and Loop antennas
Course Outcomes:

- To get a basic insight in fundamental principles and such antenna properties that have impact on the choice of antenna solution in given situations.
- To get sufficient insight in numerical methods for reasonable and critical use of modern numerical design tool for antennas.
- To be able to creatively use advanced antennas.
- To be able to design, implement and use advanced antennas in radio systems.

Recommended Reading (Including Textbooks and Reference Books)

“Antenna Theory: Analysis and Design”, by Constantine A. Balanis,

AV-845 RF MEMS for Modern Communication Systems

Credit Hours: 3

Pre-requisites: AV-231: EM Theory or equivalent basic EM course
Basic understanding of engineering Mechanics and material

Courses Objectives:

This advanced course in Microwave Engineering focuses on the modeling, design, technology and applications of RF Micro-Electro-Mechanical Systems (MEMS). Students will develop a strong understanding of RF MEMS technology and its applications on the future generation of communication systems, radars and sensors. The class begins by introducing linear and non-linear electromechanical models for RF MEMS devices through analytical and numerical techniques. The high potential of RF MEMS on building a variety of reconfigurable high-frequency components and systems is subsequently presented in detail. Finally, several
research topics including reliability, packaging and novel architectures are introduced.

**Course Contents:**

- Introduction to RF MEMS RF MEMS vs. solid state components
  Application areas and case studies RF MEMS development around the world

- Review of basic mechanics and elements of strength of materials
  Stress and strain Stresses of beams Deflection of beams and spring constants

- Mechanical modeling of MEMS switches Static analysis Dynamic analysis

- Electromechanical modeling of MEMS

- Review of Electromagnetic analysis and modeling Transmission lines
  & high-frequency effects Scattering parameters Review of numerical techniques

- Review of MEMS fabrication Bulk micromachining surface micromachining

- Case studies of RF MEMS switches

- RF MEMS inductors

- RF MEMS varactors

- Switching networks series and shunt configurations capacitive vs. ohmic contact absorptive switches

- RF MEMS Phase shifters

- RF MEMS filters

- Research issues Reliability Packaging Novel system architectures

**Course Outcomes:**

After studying this course, the graduate will be able to apply the acquired knowledge in various research areas of RF MEMS for Modern Communication Systems
Recommended Reading (Including Textbooks and Reference Books)