Aerospace Radionavigation and Telecommunications

Bachelor's Degree in Aeronautical and Space Sciences

Emanuel A. R. Camacho

emanuel.camacho@iseclisboa.pt
earc@earc96.com

Instituto Superior de Educação e Ciências (ISEC Lisboa)

Outline

Bibliography

Aerospace Radionavigation and Telecommunications

- 45 hours
- 3 hours per week
  - First part: 1h:20min
  - Break: 20min
  - Second part: 1h:20min
- Active Learning

Aerospace Radionavigation and Telecommunications covers the communication, navigation, and surveillance (CNS) technologies that enable safe and efficient air operations, combining radio-frequency engineering, satellite systems, avionics, and regulatory standards.

Evaluation

Aerospace Radionavigation and Telecommunications (100% [20/20])

Frequencies (70% [14/20]) + Project (30% [6/20])

- Frequency 1 (35% [7/20]) (15/05/2025)
- Frequency 2 (35% [7/20]) (05/06/2025)
- Report (30% [6/20] (13/06/2025)

or

Exam (100% [20/20])

- Exam (100% [20/20])

There is no minimum score for any component of the evaluation. [10/20] is required to pass.

Table of Contents

Telecommunications

Electromagnetic Spectrum, Radio Waves, Propagation, and Environmental Influence

1. What is telecommunication?
2. What is an electromagnetic wave? (,)
3. What is the electromagnetic spectrum?
4. What is the radio frequency spectrum? ()
5. What are the frequency bands?
6. What are the radar bands?
7. An HF communications signal has a frequency of 25.674 MHz. Determine the wavelength of the signal.
8. What are the different regions of the atmosphere? ()
9. What are the propagation modes of radio waves? (,)
10. What are the effects that can occur during propagation? ()

1. What is the ionosphere, and what are its layers? (,)
2. How are radio waves affected by the ionosphere? ()
3. What are the lowest and maximum usable frequencies? ()
4. How is the maximum usable frequency calculated? ()
5. Determine the electron density in the ionosphere when the MUF is 18 MHz for a critical angle of 20°.
6. What is the silent zone and skip distance? ()
7. What is space weather, and how can it affect communications? ()
8. What are the main differences between HF, VHF, and SATCOM? (,)

Table of Contents

1. What is an antenna? (↗)
2. What is the law of reciprocity?
3. What is the isotropic radiator? (↗)
4. What is the antenna radiation pattern?
5. What is the antenna gain and directivity?
6. What are some types of antennas and their applications?
7. What are the various bands of the spectrum used for communications?
8. Provide some examples of frequency allocations within the radio frequency spectrum.

1. Discuss VHF range and propagation. (↗)
2. What are the primary purposes of VHF communications?
3. What are VHF datalinks (VDL) and how are they used in ACARS?
4. Determine the altitude of an aircraft that would provide a line-of-sight distance to a ground station located at a distance of 125 nm.
5. Discuss HF range and propagation. (↗)
6. Explain why different frequencies are used for HF aircraft communications during the day and at night. (↗)
7. What are the primary purposes of HF communications?
8. What is Selective Calling (SELCAL)?
9. What are HF datalinks (HFDL) and how do they differ from VHF datalinks (VDL)? Under what circumstances is HFDL used, and what advantages does it offer? (↗)

Table of Contents

1. What is navigation?
2. How do we define a unique two-dimensional position on the Earth's surface? (↗)
3. How is the degree (°) related to minutes and seconds?
4. What is the bearing? (↗)
5. What is the magnetic north, true north, and magnetic variation? (↗)
6. What is a track, a great circle, and a rhumb line? (↗, ↗)
7. What is the great circle distance between Lisbon and New York?
8. Where on the earth's surface is the difference between a rhumb line and a great circle route the greatest?
9. How is the nautical mile linked to the Earth's geometry?
10. An aircraft flew 500 miles in two hours. What is its average speed in knots?

1. What is dead reckoning?
2. What is the drift angle? (↗)
3. For a given airspeed, explain how tailwinds and headwinds affect groundspeed. (↗)
4. What is position fixing and pinpointing? (↗)
5. What are navigation aids?
6. What are the differences between $\theta - \theta$, $\rho - \theta$ and $\rho - \rho$ positions?
7. Explain the difference between Mercator and Lambert projections. (↗, ↗)
8. In navigation terminology, what are XTK, DSRTK, DIS, DA, TK, HDG, POS, TKE, WD, TAS, WS, and GS? (↗)
9. Explain the terms Accuracy, Integrity, Availability, Continuity, and Coverage in the context of navigation systems.

Table of Contents

1. What is the Automatic Direction Finder (ADF)?
2. What is the typical range of ADF, and in which frequency bands does it operate?
3. What is the loop antenna? (↗)
4. Why is there a need to add the sense antenna? (↗)
5. What is an NDB? (↗)
6. How are NDBs identified? (↗)
7. What is a Radio Magnetic Indicator (RMI), and how can you use it to navigate with ADF? (↗, ↗, ↗, ↗, ↗)
8. Some NDBs are used as part of the final approach procedures for an airfield. How are they called?
9. What are the susceptibilities of ADF radio waves? (↗, ↗, ↗)
10. What is ADF homing? (↗)

LCP1: Flight using ADF[1]

1. Simulator: GeoFS
2. Aircraft: Cessna 172

1. Departure from LPPT (right-click on runway 03, select 5000 ft)
2. NDB Cascais (359 kHz)
3. NDB Caparica (389 kHz)
4. Tune to NDB Montijo (322 kHz) above Tagus river.
5. NDB Lisboa (401 kHz)
6. End of mission.

[1] Some navaids can be out of date.

1. What is the VHF Omnidirectional Range (VOR)?
2. What is the typical range of VOR, and in which frequency bands does it operate?
3. How does an aircraft's altitude affect the system's usable range?
4. How can the crew identify a specific VOR navigation aid?
5. What is a radial? To what are they consistently referenced?
6. What are Conventional VOR (CVOR) stations and how do they operate?
7. What is Doppler VOR (DVOR), how does it work, and what is its operational advantage?
8. What are reporting points, and how are they defined with VOR?
9. What are the Radio Magnetic Indicator (RMI), Omni-Bearing Selector (OBS), Course Deviation Indicator (CDI), and Horizontal Situation Indicator (HSI), and how do they assist while using VOR to navigate? How is a VOR radial captured?

Flight using VOR[2]

1. Simulator: GeoFS
2. Aircraft: Airbus A350

1. Departure from LPPT (right-click on runway 03, select 5000 ft)
2. VOR [LIS] (114.8 MHz) (intercept radial 270°)
3. VOR [CAS] (114.3 MHz) (intercept radial 180°)
4. VOR [ESP] (112.5 MHz) (intercept radial 135°)
5. VOR [MOJ] (110.0 MHz) (intercept radial 000°)
6. End of mission.

[2]Some navaids can be out of date.

1. What are the differences between the Primary Radar and Secondary Radar?
2. What is the Distance Measuring Equipment (DME)?
3. What is the typical range of VOR, and in which frequency bands does it operate?
4. What is the slant range?
5. What is a transponder?
6. How many positions are available while using two DMEs ($\rho - \rho$)?
7. When a DME is co-located with a VOR, what type of fix is available?
8. How do we select a DME when it is co-located with a VOR?
9. What is a TACAN and a VORTAC?
10. What is a Radio Distance Magnetic Indicator (RDMI)?

Flight using DME[3]

1. Simulator: GeoFS
2. Aircraft: F-16 Fighting Falcon

1. Departure from LPPT (right-click on runway 21, select 5000 ft)
2. VOR [LIS] (114.8 MHz) (intercept radial 180°)
3. VOR [ESP] (112.5 MHz) (intercept radial 066°)
4. Drop a bomb at 15.4 nm from ESP.
5. VOR [MOJ] (110.0 MHz) (intercept radial 000°)
6. End of mission.

[3] Some navaids can be out of date.

1. What is the Instrument Landing System (ILS)?
2. In which frequency bands does ILS operate?
3. What are the localizer, glide slope, and marker beacons?
4. Where is the localizer positioned?
5. How is the aircraft's lateral deviation determined?
6. How is the localizer identified?
7. Where is the glide slope positioned?
8. What is frequency pairing, and how is it used in the glide slope?
9. How is the aircraft's vertical deviation determined?
10. How do marker beacons inform the crew about their ILS approach progress?

1. How are the Omni-Bearing Selector (OBS), Course Deviation Indicator (CDI), Horizontal Situation Indicator (HSI), or Electronic Horizontal Situation Indicators (EHSI) used in an ILS approach?
2. What is lateral and vertical guidance?
3. What is the Low Range Radio Altimeter (LRRA), and how is it used in the ILS system?
4. What is the decision height (DH)?
5. What is the capture procedure for an ILS approach?
6. What is Autoland, what are the Autoland categories, and how are they defined?
7. What is the flare mode?
8. How can the ILS be used in the post-touchdown phase?
9. What are the operational limitations of the ILS?

Approach using ILS[4]

1. Simulator: GeoFS
2. Aircraft: Boeing 777-300ER

1. Departure from LPPT (right-click on runway 03, select 5000 ft)
2. VOR [LIS] (114.8 MHz) (intercept radial 210°)
3. When at 17.0 nm from LIS, turn left heading 090°
4. Prepare ILS approach for runway 03 (109.1 MHz). Intercept at 3000 ft.
5. End of mission.

[4]Some navaids can be out of date.

1. What is the Microwave Landing System (MLS)?
2. In which principle does MLS operate?
3. What is azimuth and elevation guidance?
4. How is ranging accomplished in an MLS?
5. What can MLS transmit aside from guidance?
6. What are its advantages over ILS?
7. What is the basic ground equipment required for an MLS approach?
8. Why can an MLS be advantageous for use in mountainous areas or in areas of high population?
9. Why does MLS provide more air traffic control flexibility?

1. What is Doppler Navigation?
2. What is the Doppler effect and Doppler shift?
3. How can ground speed be calculated?
4. How does aircraft pitch affect the Doppler shift? How can this be overcome?
5. What is drift, and how can it be determined in Doppler navigation?
6. What are some common beam arrangements?
7. In which frequency range do Doppler navigation systems typically operate?
8. How can we obtain distance travelled, cross-track deviations, and vertical displacement from Doppler velocity sensors?
9. Why can short-term velocity calculations be inaccurate over tidal waters?
10. How can Doppler navigation be useful during hovering operations in a SAR mission?

1. What is Area Navigation (RNAV)?
2. What are waypoints in an RNAV system, and how can they be generated?
3. What is an NDB, and how regularly is it updated?
4. What is a navigation leg?
5. How can waypoints be defined with a combination of VOR and DME?
6. Explain why RNAV systems using VOR–DME are generally unavailable beyond land and its immediate coastal regions.
7. What are four-dimensional waypoints?
8. What are the benefits of RNAV?
9. What is the Direct-to capability?
10. What is the Control Display Unit (CDU)?

1. How is the Course Deviation Indicator (CDI) and the Horizontal Situation Indicator (HSI) used in RNAV operations?
2. What are Standard Instrument Departures (SIDs)?
3. What are Standard Terminal Arrival Routes (STARs)?
4. What is Required Navigation Performance (RNP)?
5. What is Performance-Based Navigation (PBN)?
6. What are the system errors of PBN?
7. What is Basic RNAV (BRNAV)?
8. What are the typical and recommended functions of BRNAV?

RNAV[5]

1. Simulator: GeoFS
2. Aircraft: ???

1.
2. Departure from LPPT (right-click on runway 03, select 5000 ft)
3. VOR [LIS] (114.8 MHz) (intercept radial 220°)
4. When at 17.0 nm from LIS, turn left heading 090°
5. Prepare ILS approach for runway 03 (109.1 MHz). Intercept at 3000 ft.
6. End of mission.

[5] Some navaids can be out of date.

1. What is an Inertial Navigation System (INS)?
2. What is an accelerometer, and how does it work?
3. What is a gyroscope, and how does it work?
4. What is the difference between a Ring Laser Gyro (RLG) and a Fiber Optic Gyroscope (FOG)?
5. How is mathematical integration used to obtain velocity and distance travelled?
6. What is an Inertial Reference Unit (IRU)?
7. How does the navigation processor compensate for Gravity, Rotation, and Geometry?
8. What is the alignment process?
9. How can we improve inertial navigation accuracy with other navaids?
10. What are the main advantages and disadvantages of INS?

1. What is the Global Navigation Satellite System (GNSS)?
2. What is GPS, and in which frequency bands do GPS signals operate?
3. What is the principle of Satellite-based navigation?
4. How is the position determined using satellites?
5. What are the GPS segments?
6. What is the pseudorange?
7. What is the difference between ephemeris and almanac data?
8. What was Selective Availability?
9. What are some of the GNSS vulnerabilities?
10. What is GNSS augmentation?

1. What is the Weather Radar?
2. In which frequency bands does weather radar operate?
3. What is the underlying principle of weather radar?
4. Why are planar array flat-plate antennas used instead of the earlier parabolic dish?
5. How can clouds be classified? How does precipitation vary with each cloud type?
6. What are the conditions to create thunderstorms?
7. How is wind shear created, and how are microbursts detected?
8. How are water droplets detected?
9. What is Predictive Wind Shear (PWS), and what is its working principle?
10. What is a secondary use of the weather radar system?

1. What are Air Traffic Control Systems?
2. What is ATC based on, and in which frequency band does it operate?
3. Which ATC units (tower, ground, approach/departure, area/center) handle each phase of flight, and what are their core responsibilities?
4. What are the differences between ATC transponder Modes A, C, and S?
5. What are the three emergency ATC codes?
6. What is ADS-B?
7. How do ATC and pilots use ADS-B and what are its operational benefits?

1. What is TCAS?
2. What is TCAS based on?
3. How many types of TCAS are in operation, and what are the differences?
4. What is the closest point of approach (CPA), protected volume of airspace, and time to CPA?
5. How are traffic advisories announced in the cockpit?
6. How are resolutions advisories announced in the cockpit?
7. How does RA work between two TCAS II-equipped aircraft, and why are complementary advisories important?
8. In the event of conflicting ATC instructions and an RA, which has priority, and what is the standard pilot response procedure?

Aerospace Radionavigation and Telecommunications

Bachelor's Degree in Aeronautical and Space Sciences

Emanuel A. R. Camacho

emanuel.camacho@iseclisboa.pt
earc@earc96.com

Instituto Superior de Educação e Ciências (ISEC Lisboa)