

Aerospace Radionavigation and Telecommunications

Bachelor's Degree in Aeronautical and Space Sciences

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Outline

- 1 Introduction
- 2 Telecommunications
- 3 Radionavigation

- Mike Tooley and David Wyatt, Aircraft Communications and Navigation Systems, Third edition, Routledge, USA, 2024.
- Stanisław Rosłonec, Fundamentals of the Radiolocation and Radionavigation, First Edition, Springer, 2023.
- KLM Flight Academy, Radio Navigation: Air Transport Pilot's Licence, Nordan AS, 2015.

Aerospace Radionavigation and Telecommunications

- 45 hours
- 4 hours per week (classes of 2 hours)
 - First part: 50min
 - Break: 20min
 - Second part: 50min
- 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.

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

Frequency (60% [12/20]) + Project (40% [8/20])

- Frequency (60% [12/20]) (05/01/2026 & 06/01/2026)
- Project (40% [8/20]) (16/01/2026)

or

Exam (100% [20/20])

- Exam (100% [20/20])

[10/20] is required to pass.

Telecommunications

Telecommunications

Electromagnetic Spectrum, Radio Waves, Propagation, and Environmental Influence

- ① What is telecommunication?
- ② What is an electromagnetic wave? ([!\[\]\(36f8637baaa56c4be44b454435949289_img.jpg\)](#), [!\[\]\(b556e0ef1e10ccfc32976edb6416074f_img.jpg\)](#))
- ③ What is the electromagnetic spectrum?
- ④ What is the radio frequency spectrum? ([!\[\]\(cf1529ba638f0498d7e334e7a79dd058_img.jpg\)](#))
- 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? ([!\[\]\(2c071b2b285393c82ac6838d54fa5656_img.jpg\)](#))
- ⑨ What are the propagation modes of radio waves? ([!\[\]\(bda2070c29c668b13a0cf5b37bc9c21e_img.jpg\)](#), [!\[\]\(4dc7f5c797d7cb1aa70e6a60bb01318c_img.jpg\)](#))
- ⑩ What are the effects that can occur during propagation? ([!\[\]\(8c14435c4129a2a291714ff8aa0140d6_img.jpg\)](#))

Telecommunications

Electromagnetic Spectrum, Radio Waves, Propagation, and Environmental Influence

- ① What is the ionosphere, and what are its layers? ([!\[\]\(9063468a59e93f469b71000ac5796bc3_img.jpg\)](#), [!\[\]\(1db6320223680ab4bd04b0d269ab6c8a_img.jpg\)](#))
- ② How are radio waves affected by the ionosphere? ([!\[\]\(cd69309a3e813d8c682e56d54a0f4a01_img.jpg\)](#))
- ③ What are the lowest and maximum usable frequencies? ([!\[\]\(10da5836d64f6bfda0e81f64eb06c09d_img.jpg\)](#))
- ④ How is the maximum usable frequency calculated? ([!\[\]\(64ffe1f7747b0ebf9d3de05413a827ba_img.jpg\)](#))
- 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? ([!\[\]\(48ca033094687ae35179967b129920cd_img.jpg\)](#))
- ⑦ What is space weather, and how can it affect communications? ([!\[\]\(62aee36f74ae3183ab09e8d3ffe50364_img.jpg\)](#))
- ⑧ What are the main differences between HF, VHF, and SATCOM? ([!\[\]\(751c9e446f61c8f82144499002de1a38_img.jpg\)](#), [!\[\]\(eb803b8fdde7500bcf82afed11b47c67_img.jpg\)](#))

Telecommunications

Antennas and Frequency Bands

- 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 How can we transmit information using radio waves?
- ⑧ What are the main steps while sending signals through radio waves?
- ⑨ What are the various bands of the spectrum used for communications?
- ⑩ Provide some examples of frequency allocations within the radio frequency spectrum.

Telecommunications

Communications in the Radio Frequency Spectrum

- ① Discuss VHF range and propagation. ([!\[\]\(ef9d0f80c5c0f7b4bed9fcc98d310922_img.jpg\)](#))
- 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. ([!\[\]\(999a5e3fc9b7a6ab64b477dbcd2c0571_img.jpg\)](#))
- ⑥ Explain why different frequencies are used for HF aircraft communications during the day and at night. ([!\[\]\(4a22a098f67aa2577f972ec4d67f1799_img.jpg\)](#))
- 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? ([!\[\]\(cc98cec0bccb74dd8513e7d4ab71b1e8_img.jpg\)](#))

Radionavigation

Radionavigation

Aircraft Navigation

- ① What is navigation?
- ② How do we define a unique two-dimensional position on the Earth's surface? ([!\[\]\(35cbf67bffc0c0bbc1bfb4f3ea42174c_img.jpg\)](#))
- ③ How is the degree ($^{\circ}$) related to minutes and seconds?
- ④ What is the bearing? ([!\[\]\(a94ed5ed0aff431122d3d965b1b4bfba_img.jpg\)](#))
- ⑤ What is the magnetic north, true north, and magnetic variation? ([!\[\]\(ad849fca94bf94343f5c9b154cd2a582_img.jpg\)](#))
- ⑥ What is a track, a great circle, and a rhumb line? ([!\[\]\(bcfed9ccf9b450d49231998b7ea275cb_img.jpg\)](#), [!\[\]\(faf8a02d91c02ab3882d817a711a153e_img.jpg\)](#))
- 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?

Radionavigation

Aircraft Navigation

- 1 What is dead reckoning?
- 2 What is the drift angle? ([!\[\]\(d25e96b37004bb0da300e6da96ee0cd4_img.jpg\)](#))
- 3 For a given airspeed, explain how tailwinds and headwinds affect groundspeed. ([!\[\]\(d3aa9c337ac999b14e00b7d8b3eddb7b_img.jpg\)](#))
- 4 What is position fixing and pinpointing? ([!\[\]\(ab79838378ac037f4cb6d7f5a97bf3d7_img.jpg\)](#))
- 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. ([!\[\]\(7c71e3de03a819b7752b2c78e9a5360a_img.jpg\)](#), [!\[\]\(01d650d17a45bc8a29eb2646a16957d3_img.jpg\)](#))
- 8 In navigation terminology, what are XTK, DSRTK, DIS, DA, TK, HDG, POS, TKE, WD, TAS, WS, and GS? ([!\[\]\(7d584cf94017c826ed268aba218b4d3c_img.jpg\)](#))
- 9 Explain the terms Accuracy, Integrity, Availability, Continuity, and Coverage in the context of navigation systems.

Radionavigation

Automatic Direction Finder (ADF)

- 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 ADF¹

- 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.

¹Some nav aids can be out of date.

Radionavigation

VHF Omnidirectional Range (VOR)

- ❶ What is the VHF Omnidirectional Range (VOR)?
- ❷ What is the typical range of VOR, and in which frequency bands does it operate?
- ❸ How does an aircraft's altitude affect the system's usable range? ([↗](#))
- ❹ How can the crew identify a specific VOR navigation aid? ([↗](#))
- ❺ What is a radial? To what are they consistently referenced? ([↗](#))
- ❻ What are Conventional VOR (CVOR) stations and how do they operate? ([↗](#), [↗](#), [↗](#))
- ❼ What is Doppler VOR (DVOR), how does it work, and what is its operational advantage? ([↗](#), [↗](#), [↗](#))
- ❽ What are reporting points, and how are they defined with VOR? ([↗](#))
- ❾ 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 VOR²

- 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.

²Some nav aids can be out of date.

Radionavigation

Distance Measuring Equipment (DME)

- ❶ What are the differences between the Primary Radar and Secondary Radar? (,)
- ❷ What is the Distance Measuring Equipment (DME)? ()
- ❸ What is the typical range of DME, and in which frequency bands does it operate? ()
- ❹ What is the slant range? ()
- ❺ What is a transponder? (), ()
- ❻ How many positions are available while using two DMEs ($\rho - \rho$)? ()
- ❼ When a DME is co-located with a VOR, what type of fix is available?
- ❽ How do we select a DME when it is co-located with a VOR?
- ❾ What is a TACAN and a VORTAC? (, ,)
- ❿ What is a Radio Distance Magnetic Indicator (RDMI)? (, , ,)

LCP2: Flight using VOR/DME³

- 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.

³Some nav aids can be out of date.

Radionavigation

Instrument Landing System (ILS)

- ① What is the Instrument Landing System (ILS)?
- ② What are the localizer, glide slope, and marker beacons?
- ③ In which frequency bands does ILS operate?
- ④ Where is the localizer positioned? ([!\[\]\(a127bdbb5ffd29fba0b7fadb4346adb9_img.jpg\)](#), [!\[\]\(6e3e2bb9c574159846add9782d503778_img.jpg\)](#), [!\[\]\(02b1ead55e768dbe055b1f8423451e91_img.jpg\)](#))
- ⑤ How is the aircraft's lateral deviation determined?
- ⑥ How is the localizer identified?
- ⑦ Where is the glide slope positioned? ([!\[\]\(8dd32c22345d347417245cf5e1aae039_img.jpg\)](#), [!\[\]\(ad2aac50c887c040c0d1e72931c3ea28_img.jpg\)](#))
- 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? ([!\[\]\(87c5502e308d85a9e255bdec8cf86412_img.jpg\)](#), [!\[\]\(afc2324a1a87468c9663d2fa5844ade6_img.jpg\)](#))

Radionavigation

Instrument Landing System (ILS)

- 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 (LRRRA), 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 ILS⁴

- 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.

⁴Some nav aids can be out of date.

Radionavigation

Microwave Landing System (MLS)

- 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?

Radionavigation

Global Navigation Satellite Systems (GNSS)

- ❶ What is the Global Navigation Satellite System (GNSS)?
- ❷ What is GPS, and in which frequency bands do GPS signals operate?
- ❸ What is the principle of Satellite-based navigation?
- ❹ How is the position determined using satellites? ([!\[\]\(2238d8c4acff0b2ed98f4015280974e9_img.jpg\)](#), [!\[\]\(2f87194c89ef6c0744b7efd5fae3c758_img.jpg\)](#))
- ❺ What are the GPS segments? ([!\[\]\(a5159517e2ed68bf6370e786a30929bf_img.jpg\)](#))
- ❻ What is the pseudorange? ([!\[\]\(312c8aab0eda558e5c29e5abc9a78e97_img.jpg\)](#), [!\[\]\(36cb6752e65b0f58226fae2e068a91b5_img.jpg\)](#))
- ❼ What is the difference between ephemeris and almanac data?
- ❽ What was Selective Availability?
- ❾ What are some of the GNSS vulnerabilities?
- ❿ What is GNSS augmentation?

Radionavigation

Inertial Navigation Systems (INS)

- ❶ What is an Inertial Navigation System (INS)?
- ❷ What is an accelerometer, and how does it work? ([!\[\]\(23dfdf0d84a535693bdfe659ed1b68f5_img.jpg\)](#), [!\[\]\(66f38c9c08606374e41c874cdd55e09f_img.jpg\)](#), [!\[\]\(f9b655970a22eca1047cb640e2c36f1a_img.jpg\)](#), [!\[\]\(bfb0c5f07132ede64583a0baac7d48c2_img.jpg\)](#))
- ❸ What is a gyroscope, and how does it work?
- ❹ What is the difference between a Ring Laser Gyro (RLG) and a Fiber Optic Gyroscope (FOG)? ([!\[\]\(02df8e796b4adbf8fa02e8c9e93cfa71_img.jpg\)](#), [!\[\]\(1f924bce930eb34a6dd66e1ad414fcab_img.jpg\)](#), [!\[\]\(a83b615cfa2acec0bcb0827e6b105bc7_img.jpg\)](#))
- ❺ How is mathematical integration used to obtain velocity and distance travelled? ([!\[\]\(61cde4bf1bc78871cd5b80d7a46b7f1b_img.jpg\)](#), [!\[\]\(cf774e33d142ad0dc39b1798d5d66f4f_img.jpg\)](#))
- ❻ What is an Inertial Reference Unit (IRU)?
- ❼ How does the navigation processor compensate for Gravity, Rotation, and Geometry? ([!\[\]\(b71cc96aef136ed7af390b9713ac3a50_img.jpg\)](#))
- ❽ What is the alignment process? ([!\[\]\(73e40ae776b7b22f85af27e07ae50ebb_img.jpg\)](#), [!\[\]\(388da0fb2e476c738a03f5a9b66debda_img.jpg\)](#), [!\[\]\(c6d41c86225277c52d689ab6fb40d608_img.jpg\)](#), [!\[\]\(c72ce4e91cf446bd6433196425ec81cb_img.jpg\)](#))
- ❾ How can we improve inertial navigation accuracy with other nav aids?
- ❿ What are the main advantages and disadvantages of INS?

Radionavigation

Doppler Navigation

- ① What is Doppler Navigation?
- ② What is the Doppler effect and Doppler shift? ([!\[\]\(5c7d278cafc95e469a28c5619b31ce08_img.jpg\)](#))
- ③ How can ground speed be calculated? ([!\[\]\(755a283623ebb11fe7e7a12a67f36d52_img.jpg\)](#))
- ④ How does aircraft pitch affect the Doppler shift? How can this be overcome? ([!\[\]\(a629cbd4c72890cc1479b34f69d20257_img.jpg\)](#))
- ⑤ What is drift, and how can it be determined in Doppler navigation? ([!\[\]\(3f7d46d93f0b6195236384b8028831ec_img.jpg\)](#))
- ⑥ What are some common beam arrangements? ([!\[\]\(d5f12fb132d27e6c0e341bff29828161_img.jpg\)](#))
- 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? ([!\[\]\(8ab1f94a832744321c18a4cefc8b9913_img.jpg\)](#), [!\[\]\(037126f3e7db5ecefd94bede834e2a3e_img.jpg\)](#))
- ⑩ How can Doppler navigation be useful during hovering operations in a SAR mission?

Radionavigation

Area Navigation (RNAV)

- 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)?

Radionavigation

Area Navigation (RNAV)

- 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?

RNAV⁵

① Simulator: [GeoFS](#)

② Aircraft: ???

③

④ Departure from LPPT (right-click on runway 03, select 5000 ft)

⑤ VOR [LIS] (114.8 MHz) (intercept radial 220°)

⑥ When at 17.0 nm from LIS, turn left heading 090°

⑦ Prepare ILS approach for runway 03 (109.1 MHz). Intercept at 3000 ft.

⑧ End of mission.

⁵Some nav aids can be out of date.

- ❶ What is the Weather Radar?
- ❷ In which frequency bands does weather radar operate?
- ❸ What is the underlying principle of weather radar?
- ❹ Why are planar array flat-plate antennas used instead of the earlier parabolic dish?
- ❺ How can clouds be classified? How does precipitation vary with each cloud type?
- ❻ What are the conditions to create thunderstorms?
- ❼ How is wind shear created, and what are microbursts?
- ❽ How are water droplets detected?
- ❾ What is Predictive Wind Shear (PWS), and what is its working principle?
- ❿ What is a secondary use of the weather radar system?

Radionavigation

Air Traffic Control Systems (ATC)

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

Radionavigation

Traffic Alert and Collision Avoidance Systems (TCAS)

- 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 resolution 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?

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