Unit 88: Aircraft Radio and Radar Principles

Unit code: D/600/7311

QCF Level 3: BTEC Nationals

Credit value: 10

Guided learning hours: 60

Aim and purpose

This unit will develop learners' understanding of the principles of aircraft communications and navigation systems.

Unit introduction

Modern aircraft make extensive use of complex avionic systems for communication and navigation. These systems rely primarily on radio and radar for their operation.

This unit provides an introduction to the principles of aircraft communications and navigation systems. Learners will gain an understanding of radio waves and how radio transmitters and receivers operate. They will also look at the operation and use of aircraft radio and radar antennas. Learners will gain an understanding of the principles, characteristics and applications of the different systems used for aircraft navigation and the operation of radar systems.

The unit covers the essential underpinning knowledge needed by those involved in the design, manufacture and maintenance of military and commercial aircraft radio and radar systems. The unit also provides some of the knowledge and understanding for learners wishing to progress on to category B of the European Aviation Safety Agency (EASA) Part 66 licensing requirements, Module 13.

Learning outcomes

On completion of this unit a learner should:

1 Understand the principles and operation of aircraft radio transmitters and receivers

2 Understand the principles and operation of aircraft radio and radar antennas and feeders

3 Understand the principles and operation of aircraft navigation systems

4 Understand the principles and operation of aircraft radar systems.

Unit content

1 Understand the principles and operation of aircraft radio transmitters and receivers

Radio principles: radio waves (ground, sky, space); radio wave propagation at different frequencies eg very low (VLF), low (LF), medium (MF), high (HF), very high (VHF), ultra high (UHF), super high (SHF); principles, characteristics and applications of different modulation methods eg amplitude modulation (AM) (including DSB and SSB), single-sideband (SSB), frequency modulation (FM), digital modulation (Frequency-shift keying (FSK), Phase-shift keying (PSK), differential phase-shift keying (DPSK))

Transmitters: principles, operation, characteristics and applications of transmitters eg AM, FM and SSB and for use at different frequencies such as HF, VHF (datalinks VDL and HFDL), and UHF, aircraft communication addressing and reporting system (ACARS); block schematic diagrams of transmitters showing internal functional blocks eg oscillators, frequency multipliers, mixers, frequency synthesisers, phase-locked loops (PLL), modulators, filters, compressors, automatic level control (ALC), antenna matching units; typical transmitter specifications eg output power, frequency range, frequency accuracy, frequency stability, number of channels, modulation depth

Receivers: principles, operation, characteristics and applications of receivers eg tuned radio frequency (TRF), single superhets, double superhets; block schematic diagrams of receivers showing internal functional blocks eg radio frequency (RF) amplifiers, mixers, oscillators, frequency synthesisers, phase-locked loops (PLL), intermediate frequency (IF) amplifiers, filters, automatic gain control (AGC), automatic frequency control (AFC), demodulators; typical receiver specifications eg image channel rejection, adjacent channel rejection, sensitivity, frequency range, frequency accuracy, frequency stability, number of channels

2 Understand the principles and operation of aircraft radio and radar antennas and feeders

Antennas: principles, operation, characteristics and applications of radio and radar antennas eg isotropic radiator, half-wave dipole, quarter wave unipole, beam, ground-plane, discone, loaded monopole, helical, parabolic reflector, phased array, rod, slot, loop, plate, horn and dielectric types; uses (HF, VHF)

Feeders: principles, operation, characteristics and applications of coaxial (flexible and rigid) and waveguide (rigid and flexible) feeders; feeder specifications eg characteristic impedance, loss, frequency response and power handling

3 Understand the principles and operation of aircraft navigation systems

Navigation systems: principles, operation, characteristics and applications of systems used for aircraft navigation eg VHF omnidirectional range (VOR) tactical air navigation (TACAN), distance measuring equipment (DME), automatic direction finding (ADF), instrument landing system (ILS), microwave landing system (MLS), hyperbolic navigation system, Doppler navigation, global positioning system (GPS), global navigation satellite systems (GNSS), in-flight meteorological information (VOLMET), VLF/Omega; typical performance specifications for aircraft navigation systems eg operating frequency/frequency band, accuracy, maximum range, availability, reliability

4 Understand the principles and operation of aircraft radar systems

Radar: principles, operation, characteristics and applications of primary and secondary pulsed and continuous wave (CW) radar transmitters eg radar altimeter, secondary surveillance radar (SSR), weather radar (WXR), traffic alert and collision avoidance system (TCAS); block schematic diagrams of radar showing internal functional blocks eg mixer, oscillator, intermediate frequency (IF) amplifier, demodulator, clutter reduction, sensitivity time control (STC), automatic frequency control (AFC), magnetron, klystron, travelling wave tube (TWT), Gunn effect diode, high power oscillator (HPO) and master oscillator power amplifier (MOPA); factors affecting the performance of radar systems eg slant range, bearing, elevation angle, clutter, transmitter power, receiver sensitivity, frequency of operation, beam shape and scanning method, pulse repetition frequency (PRF), pulse duration (PD); typical radar specifications eg operating frequency/frequency band, accuracy, maximum range, resolution/target discrimination, peak and mean operating power, pulse repetition frequency

Assessment and grading criteria

In order to pass this unit, the evidence that the learner presents for assessment needs to demonstrate that they can meet all the learning outcomes for the unit. The assessment criteria for a pass grade describe the level of achievement required to pass this unit.

Assessment and grading criteria		
To achieve a pass grade the evidence must show that the learner is able to:	**To achieve a merit grade the evidence must show that, in addition to the pass criteria, the learner is able to:**	**To achieve a distinction grade the evidence must show that, in addition to the pass and merit criteria, the learner is able to:**
P1 explain the principles of radio wave propagation (ground waves, sky waves and space waves) at different frequencies (LF, MF, HF, UHF and above)	**M1** describe a typical application for an aircraft voice communication system and give a typical specification for the equipment used	**D1** evaluate the performance of two different aircraft navigation systems with reference to their application, performance specification and the antennas used
P2 explain the different methods of modulation	**M2** describe a typical application for an aircraft navigation system and give a typical specification for the equipment used	**D2** evaluate the performance of two different aircraft radar systems with reference to their application, performance specification and the antennas used.
P3 explain the principles, characteristics, application and specifications of a typical aircraft radio transmitter with reference to a labelled block schematic diagram	**M3** describe a typical application for an aircraft radar system and give a typical specification for the equipment used.	
P4 explain the principles, characteristics, application and specifications of a typical aircraft radio receiver with reference to a labelled block schematic diagram		
P5 explain the principles, operation, characteristics and specifications of two different types of aircraft radio antenna (one for use at HF and one for use at VHF)		
P6 explain the principles, operation, characteristics and specifications of coaxial and waveguide feeders		

Assessment and grading criteria			
To achieve a pass grade the evidence must show that the learner is able to:		**To achieve a merit grade the evidence must show that, in addition to the pass criteria, the learner is able to:**	**To achieve a distinction grade the evidence must show that, in addition to the pass and merit criteria, the learner is able to:**
P7	explain the principles, operation, characteristics, applications and performance specifications of three different aircraft navigation systems		
P8	explain the principles, operation, characteristics, applications and specifications of typical primary and secondary, pulsed and continuous wave radar transmitters with reference to labelled block schematic diagrams [IE4]		
P9	describe the factors affecting radar system performance for a given radar specification.		

PLTS: This summary references where applicable, in the square brackets, the elements of the personal, learning and thinking skills applicable in the pass criteria. It identifies opportunities for learners to demonstrate effective application of the referenced elements of the skills.

Key	IE – independent enquirers	RL – reflective learners	SM – self-managers
	CT – creative thinkers	TW – team workers	EP – effective participators

Essential guidance for tutors

Delivery

This unit is designed to give prospective avionics technicians the understanding of aircraft communications and radar systems needed to work safely and effectively in an aircraft environment. Learners will gain an understanding of the specific health and safety issues associated with aircraft communications and radar systems and equipment (notably hazardous electromagnetic fields and high voltages).

Although this is primarily a theoretical unit, delivery would be enhanced through the use of real communication and radar systems/equipment. The amount of any practical input will be largely dependent on the resources available. Where centre resources are limited or no suitable partnership with industry can be arranged visits to aircraft maintenance organisations and aircraft operators should be used. In addition, visits to museums such as those at Duxford, Brooklands and Yeovilton will provide learners with access to static aircraft of various types.

Although this subject requires substantial tutor input, learners should be encouraged to take responsibility for their own learning, whenever appropriate.

Each of the four learning outcomes of this unit are linked and the delivery strategy should ensure that these links are maintained. Learning outcome 1 is the most likely starting point for delivery, as it will establish much of the underpinning knowledge required for the remaining learning outcomes. The unit could be delivered through a combination of theory lessons and demonstrations, reinforced through practical investigations where possible (for example measurement of the E-plane and H-plane radiation patterns of a dipole antenna). Where learners have been employed (or are currently in employment) in the aerospace sector, they should be encouraged to draw upon their previous experience of aircraft systems.

Outline learning plan

The outline learning plan has been included in this unit as guidance and can be used in conjunction with the programme of suggested assignments.

The outline learning plan demonstrates one way in planning the delivery and assessment of this unit.

Topic and suggested assignments/activities and/assessment
Whole-class teaching: • describe radio waves, the propagation of radio waves at different frequencies and explain the principles and characteristics of modulation • explain the principles and applications of transmitters, the use of schematic diagrams and describe typical transmitter specifications • explain the principles and applications of radio receivers, the use of schematic diagrams and describe typical receiver specifications. *Practical workshop activities:* • investigation of the construction and operation of radio transmitters and receivers.
Prepare for and carry out **Assignment 1: Transmitters and Receivers** (P1, P2, P3, P4, M1).

Topic and suggested assignments/activities and/assessment
Whole-class teaching: • explain the principles, operation and applications of radio and radar antennas • explain the principles, operation and applications of radio and coaxial and waveguide feeders. *Individual learner activities:* • case study based investigation of applications of radio and radar antennas • quiz/multiple choice test on the operation of a range of different antennas.
Prepare for and carry out **Assignment 2: Antennas and Feeders** (P5, P6).
Whole-class teaching: • explain the principles, operation and applications of aircraft navigation systems • describe the typical performance specifications for aircraft navigation systems. *Individual learner activities:* • investigation of operation and applications of systems used for aircraft navigation. *Industrial visit:* • visit to aircraft operator to view aircraft navigation systems.
Prepare for and carry out **Assignment 3: Aircraft Navigation Systems** (P7, M2, D1).
Whole-class teaching: • explain the principles, operation and applications of primary and secondary pulsed and CW radar transmitters systems • describe the use of block schematic diagrams showing internal functional blocks • explain the factors that can affect the performance of radar systems and describe typical radar specifications. *Industrial visit:* • visit to aircraft operator to view aircraft radar systems. *Individual learner activities:* • case study based investigation of aircraft applications of radar transmitters.
Prepare for and carry out **Assignment 4: Radar Systems** (P8, P9, M3, D2).
Feedback on assessment and unit review.

Assessment

It is likely that at least four assessment instruments will be required for this unit. If practical investigations and tests are also used then the total number of pieces of assessed work could be even more. This should be carefully considered so that it does not place an unduly heavy assessment burden on learners or the tutor.

The method of assessment preferred by national legislative bodies involves the use of multiple choice questions. Many centres may have existing banks of multiple choice questions designed to prepare and test learners for Module 13 of EASA Part-66. Where learners are aiming to achieve recognised licensed status, this method of assessment could be adopted as a means of supporting and checking learning. Multiple-choice questions should not, however, be used as assessment instruments for the purposes of this unit.

The first assignment could cover learning outcome 1 (P1, P2, P3, P4, M1) and is likely to consist of a series of written tasks. P1 requires learners to provide an explanation of radio wave propagation at different frequencies. An acceptable explanation should include mention of ground waves, sky waves and space waves and should include the range of frequencies normally associated with each type of propagation. Learners

should also explain how and why radio wave propagation informs the use and application of radio in aircraft. For example, learners should associate long-distance HF radio communication with single and multi-hop sky wave propagation, space wave propagation at UHF/SHF with orbiting satellites for GNSS and GPS etc.

P2 could be assessed through an investigative task into modulation techniques. Learners should be able to describe in words and using appropriate diagrams where this helps, the principles of amplitude modulation (including DSB and SSB), frequency modulation (FM), and digital modulation. Learners should also explain how and why modulation techniques inform the use of voice and data communication in aircraft. For example, learners should associate the narrow bandwidth available with HF radio systems with relatively low data rates used for High Frequency Data Link (HFDL); the wider bandwidth of VHF radio systems with faster data rates used with Very High Frequency Data Link (VDL) and the Aircraft Communication Addressing and Reporting System (ACARS).

Learners can achieve P3 by drawing a labelled block diagram of an aircraft radio transmitter (this can be either an HF or VHF unit). The diagram should include appropriate annotation and should clearly show the links between blocks. Each block should be clearly labelled with its function, for example 'Frequency Multiplier', 'Modulator', 'Antenna Filter'. Learners should provide a brief written explanation of the function of each stage as well as the overall function of the unit together with typical operational specifications and a suggested application for the unit.

For P4, learners could draw a labelled block diagram of an aircraft radio receiver (this can either be an HF or VHF unit). The diagram should include appropriate annotation and should clearly show the links between blocks. Each block should be clearly labelled with its function, for example 'RF amplifier', 'Mixer', 'IF filter'. Learners should provide a brief written explanation of the function of each stage as well as the overall function of the unit together with typical operational specifications and a suggested application for the unit.

M1 could be achieved through a detailed investigation of an aircraft voice communication system. This can be either an HF or a VHF unit. Learners should provide an adequately detailed description of how the system works and what it is used for. The description should relate specifically to the primary application of the chosen aircraft voice communication system and should include, for example, the need for ALC and AGC, channel selection using frequency synthesis and cockpit mounted control units etc. Learners should also provide a description of the application and type of traffic handled by the system, for example ATC instructions, VOLMET, as well as an outline specification including, for example, frequency range, receiver sensitivity, transmitter output power, input/output impedance, modulation types (AM, SSB, DPSK), number of channels, etc.

The second assignment could require learners to describe (using labelled sketches and a supporting written explanation) the principles of at least two antennas, for example a VHF blade antenna and HF slot antenna (P5). Feed-points should be clearly identified and the directional characteristics of each antenna should be described. For P6, an investigation of coaxial (flexible and rigid) and waveguide (flexible and rigid) feeders could be used. Learners should describe (again using labelled sketches where this may help and a supporting written explanation) the principles and operation of each types of feeder. They should also summarise the characteristics, typical operational specifications and a suggested application for each type.

A third assignment could cover P7, M2 and D1. This will need to involve an investigation of three different aircraft navigation systems (P7), such as VOR, DME, GPS/GNSS, ILS, MLS or Loran-C. Learners should describe and explain the principles on which their chosen systems operate as well as providing a summary of the characteristics and applications as well as typical specifications relevant to the systems that they have chosen.

M2 could be achieved through a detailed investigation of an aircraft navigation system. This will usually be a VHF system, such as ILS or VOR but could also be based on GPS or GNSS. Learners should provide an adequately detailed description of how the system works and what it is used for. The description should relate specifically to the primary application of the chosen aircraft navigation system and should include, for example, the need for ground-based equipment (such as beacons and antennas). Learners should also provide a

description of the application as well as an outline specification including, for example, frequency range, receiver sensitivity, transmitter output power, input/output impedance, modulation types (AM, SSB, DPSK), number of channels, etc.

D1 could be achieved through an extension of the work carried out for M2. D1 requires them to evaluate the performance of two different navigation systems (for example, evaluating hyperbolic and satellite-based systems and then providing a detailed comparison of the two systems). Learners should quote comparative specifications and should summarise advantages and disadvantages of each system investigated. Learners should be expected to relate the overall performance of a system to the properties and characteristics of the individual components (receivers, transmitters, antennas, feeders, ground-based equipment, etc) as well as the vagaries of propagation (effect of anomalous propagation, variations in MUF) noise, errors and other disturbances.

The final assignment would cover learning outcome 4 and would require learners to draw a labelled block diagram of typical primary and secondary radar systems, such as weather radar and surveillance radar systems (P8). The diagram should include appropriate annotation and should clearly show the links between blocks. Each block should be clearly labelled with its function, for example 'Magnetron', 'Directional coupler', 'IF amplifier', 'Antenna'. Learners should provide a brief written explanation of the function of each stage as well as the overall function of the unit together with typical operational specifications and a suggested application.

For P9 learners should provide a written description of the factors that affect radar performance for a given specification (such as primary or secondary surveillance radar system, and weather radar system). Their description should include references to factors such as range, target discrimination, freedom from clutter in relation to performance parameters such as peak radiated power, pulse width, antenna beam width, as relevant to the chosen system.

For M3, learners could carry out a detailed investigation of an aircraft radar system. This will usually be a weather radar system. Learners should provide an adequately detailed description of how the system works and what it is used for. The description should relate specifically to the primary application of the chosen aircraft radar system and should, for example, include the need for scanning, antenna tilt, anti-clutter, etc. Learners should also provide a description of the application as well as an outline specification including, for example, operating frequency, antenna beam width, receiver sensitivity, peak and mean output power, pulse repetition frequency, input/output impedance, etc.

Learners could achieve D2 through an extension of work carried out for M3. D2 requires them to evaluate the performance of two different aircraft radar systems (for example, evaluating a secondary radar system used for distance measurement (DME) or tactical navigation (TACAN) and a primary radar system used for weather (WXR) and then providing a detailed comparison of the two systems in terms of frequency, power, range, etc). Learners should quote comparative specifications and should summarise advantages and disadvantages of each system investigated. Learners should be expected to relate the overall performance of a system to the properties and characteristics of the individual components (receivers, transmitters, antennas, feeders, ground-based equipment, etc) as well as the vagaries of propagation (effect of anomalous propagation, ducting, rain and moisture), noise, errors, false reflections and other disturbances.

Programme of suggested assignments

The table below shows a programme of suggested assignments that cover the pass, merit and distinction criteria in the assessment and grading grid. This is for guidance and it is recommended that centres either write their own assignments or adapt any Edexcel assignments to meet local needs and resources.

Criteria covered	Assignment title	Scenario	Assessment method
P1, P2, P3, P4, M1	Transmitters and Receivers	The learner has been asked to produce a report on the operation of aircraft radio transmitters and receivers.	A written report.
P5, P6	Antennas and Feeders	The learner has been asked to produce a report on the operation of aircraft antennas and feeders.	A written report, including relevant diagrams.
P7, M2, D1	Aircraft Navigation Systems	The learner has been asked to produce a report on the operation of aircraft navigation systems.	A written report.
P8, P9, M3, D2	Radar Systems	The learner has been asked to produce a report on the operation of aircraft navigation systems.	A written report.

Links to National Occupational Standards, other BTEC units, other BTEC qualifications and other relevant units and qualifications

This unit forms part of the BTEC Engineering sector suite. This unit has particular links with:

Level 1	Level 2	Level 3
		Avionic Systems

The unit also links with parts of the EASA Part 66 syllabus, particularly the knowledge required by maintenance certifying mechanics and avionics tradesmen undergoing initial technical training in the armed forces.

Essential resources

It is accepted that apart from JAR 147 approved organisations and specialist training organisations, access to modern communications/radar systems and equipment will be severely limited. However, sight of such systems and equipment will greatly enhance delivery. Centres with limited equipment are strongly advised to incorporate a structured industrial visit into their teaching, so that learners have, at the very least, sight of aircraft radio, radar, radio navigation and opto-electronic systems and equipment.

Access to system hardware, such as transmission lines, aerials and wave-guides would also be beneficial. Computer packages, illustrating aircraft communications and radar systems and equipment would also be of tremendous benefit.

Employer engagement and vocational contexts

Much of the work for this unit can be set in the context of learners' work placements or be based on case studies of local employers. Further information on employer engagement is available from the organisations listed below:

- Work Experience/Workplace learning frameworks – Centre for Education and Industry (CEI – University of Warwick) – www.warwick.ac.uk/wie/cei/
- Learning and Skills Network – www.vocationallearning.org.uk
- Network for Science, Technology, Engineering and Maths Network Ambassadors Scheme – www.stemnet.org.uk
- National Education and Business Partnership Network – www.nebpn.org
- Local, regional Business links – www.businesslink.gov.uk
- Work-based learning guidance – www.aimhighersw.ac.uk/wbl.htm

Indicative reading for learners

Textbooks

Eismin T – *Aircraft Electricity and Electronics* (McGraw-Hill, 1994) ISBN 0711382864

Tooley M and Wyatt D – *Aircraft Communications and Navigation Systems* (Butterworth-Heinemann, 2007) ISBN 9780750681377

Delivery of personal, learning and thinking skills

The table below identifies the opportunities for personal, learning and thinking skills (PLTS) that have been included within the pass assessment criteria of this unit.

Skill	When learners are ...
Independent enquirers	analysing and evaluating information when using schematic diagrams.

Although PLTS are identified within this unit as an inherent part of the assessment criteria, there are further opportunities to develop a range of PLTS through various approaches to teaching and learning.

Skill	When learners are ...
Reflective learners	setting goals with success criteria for their development and work.

Functional Skills – Level 2

Skill	When learners are ...
English	
Speaking and listening – make a range of contributions to discussions and make effective presentations in a wide range of contexts	explaining the principles, operation, characteristics, applications and performance specifications of aircraft radio and radar systems
Reading – compare, select, read and understand texts and use them to gather information, ideas, arguments and opinions	researching and investigating aircraft radio and radar systems
Writing – write documents, including extended writing pieces, communicating information, ideas and opinions, effectively and persuasively	explaining the principles, operation, characteristics, applications and performance specifications of aircraft radio and radar systems.