062

RADIO NAVIGATION

JAR-FCL REF NO	**LEARNING OBJECTIVES**	REMARKS
062 00 00 00	**RADIO NAVIGATION**	
062 01 00 00	**RADIO AIDS**	
062 01 01 00	**Ground Direction Finder D/F (including classification of bearings)**	
	– Principles	
	– Describe the role of a Ground Direction Finder	
	– Explain why the services provided are subdivided as	
	– VHF direction finding	
	– Describe, in general terms, the propagation path of VHF/UHF signals with respect to the ionosphere and the Earth’s surface.	
	– Describe the principle of operation of the VDF in the following general terms	
	– radio waves emitted by the radio telephony (R/T) equipment of the aircraft	
	– directional antenna.	
	– determination of direction of incidence of the incoming signal	
	– Indicator	
	- Recognise the Adcock antenna with its vertical dipoles	
	– Presentation and Interpretation	
	– Describe the common types of bearing presentations on VDU and radar display.	
	– Define the terms QDM; QDR; QTE;	
	– Explain how, using more than one ground DF station, the position of an aircraft can be determined and transmitted to the pilot.	
	– Coverage and Range	

JAR-FCL REF NO	LEARNING OBJECTIVES	REMARKS
	– Calculate the line of sight range (quasi optical visual range)	
	– Errors and Accuracy	
	– State the classification of bearings.	
	– Factors affecting Range and Accuracy	
	– Explain that the range is affected by gradients of temperature and humidity	
	– Differentiate between the phenomena 'super refraction' and 'sub refraction'	
	– Explain how intervening terrain can restrict the range	
	- Explain why synchronous transmissions will cause errors	
	- Describe the effect of multipath signals	
062 01 02 00	**ADF (incl. NDB's and Use of RMI)**	
	– Principles	
	– Name the approved frequency band assigned to aeronautical NDB's (190 - 1750 kHz)	
	– Recognise typical antenna arrangements for ground station (NDB) and aircraft (ADF)	
	– Explain the difference between NDB and locator beacons	
	– State which beacons transmit input signals suitable for use by the ADF	
	– Define the abbreviation 'NDB'	
	– Describe the use of NDBs for navigation	
	– Describe the use of locator beacons	
	– Interpret the term 'cone of silence' in respect of a NDB.	
	– State that the transmission power limits the ranges for locators, en-route NDBs and oceanic NDBs.	

JAR-FCL REF NO	LEARNING OBJECTIVES	REMARKS
	- Explain why it is necessary to use a directionally sensitive receiver antenna system in order to obtain the direction of the incoming radio wave – Presentation and interpretation – Name the types of indicator in common use and state the indications given on the : – radio magnetic indicator – fixed card indicator/ radio compass – Describe and sketch the presentation on the following ADF indicators: – radio magnetic indicator (RMI) and – fixed card indicator/ radio compass – Describe the procedure for obtaining an ADF bearing including the following : – switch on instrument (on ADF), – scan frequency, – regulate volume, – receive and identify the NDB, – read bearing. – State the function of the BFO (tone generator) switch. – Calculate the compass bearing from compass heading and relative bearing. – Convert compass bearing into magnetic bearing and true bearing. – Describe how to fly the following in-flight ADF procedures (in accordance with DOC 8168 Vol.I) : – homing – tracking	

JAR-FCL REF NO	LEARNING OBJECTIVES	REMARKS
	– interceptions – procedure turns – holding patterns – Coverage and range – Describe the influence of the transmission power on the range. – Differentiate between NDB range over land and over the sea – Identify the ranges of locators, en-route NDB's and Oceanic NDB's – Describe the propagation path of NDB radio waves with respect to the ionosphere and the Earth's surface – Errors and Accuracy – Define quadrantal error and identify its cause – State that compensation for this error is effected during the installation of the antenna. – Explain the cause of the dip error due to the bank angle of the aeroplane - Define the bearing accuracy as ± 6° – Factors affecting range and accuracy – Indicate the causes and/or effects of the following factors – multipath propagation of the radio wave (mountain effect) – the influence of skywaves (night effect) – the shore line (coastal refraction) effect – atmospheric disturbances (static and lightning) – interference from other beacons.	

JAR-FCL REF NO	**LEARNING OBJECTIVES**	REMARKS
062 01 03 00	**<u>CVOR and DVOR (incl. use of RMI)</u>** – Principles – Name the frequency-band and frequencies used for VOR – Interpret the tasks of the following types of VOR: – En-route VOR – conventional VOR (CVOR) – Doppler VOR (DVOR) – Terminal VOR (TVOR) – Test VOR (VOT) – Define a VOR radial – Recognise antenna arrangements for ground facilities and for aircraft – Describe the effect of rough terrain in the immediate vicinity of the transmitter. – Explain the principle of operation of the VOR using the following general terms: – reference phase – variable phase – phase difference – Explain the use of the Doppler effect in a Doppler VOR – Describe the identification of a VOR in terms of Morse-code letters, continuous tone or dots(VOT), tone pitch, repetition rate and additional plain text – Describe how ATIS information is transmitted via VOR frequencies – Name the three main components of VOR airborne equipment	

JAR-FCL REF NO	LEARNING OBJECTIVES	REMARKS
	– Identify a VOR from the chart by chart symbol and/or frequency	
	– Presentation and Interpretation	
	– Read off the radial from the Radio Magnetic Indicator (RMI)	
	– Read off the angular displacement, in relation to a pre-selected radial, from the HSI or CDI	
	– Explain the use of the TO/FROM indicator to determine the aircraft position relative to the VOR considering also the heading of the aircraft	
	– Interpret given VOR information as displayed on HSI, CDI and RMI.	
	– Describe the following in-flight VOR procedures (in accordance with DOC 8168 Vol. 1) :	
	– homing	
	– tracking	
	– interceptions	
	– procedure turns	
	– holding patterns	
	– Enter a radial on a navigation chart, taking into account the variation at the transmitter location	
	– Coverage and Range	
	– Describe the range with respect to the transmitting power and the quasi-optical range in NM	
	– Calculate the range in NM	
	- Explain the sector limitations in respect of topography-related reflections	
	– Errors and Accuracy	

JAR-FCL REF NO	LEARNING OBJECTIVES	REMARKS
	– Describe the use of a test VOR for checking VOR indicators in an aircraft – Describe the signals emitted by the test VOR with respect to reference phase, variable phase and transmitted radial. – Identify the permissible signal tolerance - State the 95% accuracy of the VOR bearing information is within ± 5° – Factors affecting Range and Accuracy – Explain why the Doppler VOR is more accurate than the conventional VOR – Illustrate the effects of bending and scalloping of radials.	
062 01 04 00	**DME (distance measuring equipment)** - Principles – Identify the frequency band – Illustrate the use of X and Y channels. – State that a DME facility is integrated with the military TACAN – Describe the tuning of the DME frequency by the pilot – Describe the navigation value of the slant range measured by the DME – Illustrate the circular line of position with the transmitter as its centre – Describe, in the case of co-location, the frequency pairing and identification procedure – Recognise DME antennas on aircraft and on the ground – Identify a DME station on a chart by the chart symbol – Describe how the pairing of VHF and UHF frequencies (e.g. VOR/DME) enables selection of two items of navigation information (distance and direction, rho-theta) with one frequency setting – Explain the combination of transmitter/receiver in the aeroplane (interrogator) and on the ground	

JAR-FCL REF NO	LEARNING OBJECTIVES	REMARKS
	(transponder) – Explain why airborne and ground equipment use different frequencies – Describe the principle of distance determination using DME in terms of: – pair of pulses; – fixed frequency division of 63 MHz, – the propagation delay and – the 50 microseconds delay time – irregular transmission sequence – search mode – tracking mode – Differentiate between Search, Tracking and Memory modes - Explain how the combination of a DME distance with a VOR radial allows the aircraft's position to be determined – Presentation and Interpretation – Describe the identification (time sequence and frequencies) in the case of co-location with a VOR. – Describe the probable indications when in each mode of operation. – Interpret the direct distance (slant range) which is displayed in nautical miles. - Explain why DME indicators display distances up to a maximum of approx. 300 NM. – Calculate the slant range correction	

JAR-FCL REF NO	LEARNING OBJECTIVES	REMARKS
	- Describe the use of DME to fly a DME arc (in accordance with Doc 8168 Vol. I).	
	– Coverage and Range	
	– Explain why a ground station can generally respond to a maximum of 100 aircraft. Identify which aircraft will be denied first, when more than the maximum number of interrogations is made.	
	– Illustrate how the DME transponder processes more than 2700 interrogations in the DME's reception area. State how this affects the strongest signals and the closest aircraft units.	
	– Describe how the range is related to the transmitter power and the quasi-optical range in NM.	
	- Calculate the range in NM	
	– Errors and Accuracy	
	- Interpret the 95% accuracy as stated in ICAO annex 10	According to ICAO Annex 10 Vol. I par 3.5.3
	– Factors affecting Range and Accuracy	
	– Interpret the relationship between the number of users, the gain of the receiver and the range.	
	– State the maximum number of aircraft that can be handled by a DME transponder. Explain what limits this value.	
	– Illustrate the effect of bank angle hiding the antenna from the transponder on the surface, taking into consideration the time limits of the memory circuit.	
	– Explain the role of the Echo Protection Circuit in respect of reflections from the earth’s surface, buildings or mountainous terrain	
062 02 00 00	**BASIC RADAR PRINCIPLES**	
062 02 04 00	**<u>SSR (secondary surveillance radar) and Transponder</u>**	
	– Principles	
	– Name the frequencies used for interrogation and response	

JAR-FCL REF NO	LEARNING OBJECTIVES	REMARKS

	– Identify the ground antenna
	– Sketch the radiation pattern of a rotating slotted array which transmits a narrow beam in the horizontal plane
	– Explain, in general terms, how a side lobe suppressor avoids answers on interrogations via side lobes
	– Sketch the radiation pattern of the antenna of the aircraft which transmits omnidirectionally
	– Define the terms: ‘interrogator’ (on the ground) and ‘transponder’ (in the aircraft)
	– Explain that information from primary radar and secondary radar can be combined and that the radar units may be co-sited.
	– Explain the advantages of SSR over a primary radar
	– Explain the following disadvantages of SSR:
	  – code garbling of aircraft less than 1.7 NM apart measured in the vertical plane perpendicular to and from the antenna
	  - ‘fruiting’ which results from reception of replies caused by interrogations from other radar stations
	– Presentation and Interpretation
	– Explain how an aircraft can be identified by a unique code
	– Illustrate how the following information is presented on the radar screen:
	  – the pressure altitude
	  – the flight level
	  – the flight number or aircraft registration
	  – the ground speed	

JAR-FCL REF NO	LEARNING OBJECTIVES	REMARKS
	– Name and interpret the particular codes 7700, 7600 and 7500	
	– Describe how the antenna is shielded when the aircraft banks	
	- Interpret the selector modes: OFF, Stand by, ON (mode A), ALT (mode A and C) and TEST	
	- Explain the function of the emission of a SPI (Special Position Identification) pulse after pushing the ident button in the aircraft	
	– Modes and Codes, including mode-S	
	– Explain the function of the three different modes:	
	– mode A	
	– mode C	
	– mode S	
	– Explain why a fixed 24 bits address code will avoid ambiguity of codes	
	– Explain the need for compatibility of mode S with mode A and C	
	– Interpret the terms: selective addressing, mode 'all call' or selective calling	
	- State the possibility of exchanging data via communication protocols	
	- Name the advantages of mode S over mode A and C	
062 02 05 00	**Use of Radar Observations and Application to In-flight Navigation**	
	– Explain the need for radar observations of aircraft by Air Traffic Control	
	– State the two main functions of the ground radar used by the ATC **(TCAS: 022 03 04 00)**	
062 06 05 00	**Global Navigation Satellite Systems GNSS: GPS/ GLONASS**	
	- State the basic differences between the NAVSTAR/GPS system (GPS) and the GLONASS system regarding ellipsoid, time, satellite configuration, codes and frequencies	

JAR-FCL REF NO	**LEARNING OBJECTIVES**	REMARKS
	– Principles of System Operation – State the four basic information elements supplied by GPS-Navstar. – Explain why the measured distances are called pseudo ranges - Explain why the minimum requirements, to establish the 3 spatial co-ordinates and a possible error in the receiver clock, consist of the measured distances to 4 satellites and a dead reckoning(DR) position. – Describe the geometrical interpretation of the position fix using four spherical surfaces, with the satellite being in each case located at the centre of the sphere involved – Name the synchronous time system used in the satellites - Describe the C/A, P and Y code and state the use of these codes – Explain how pseudo range measurement is achieved using satellite signals - State that the conversion of pseudo ranges is carried out, by means of transformation equations, in order to obtain geodetic co-ordinates (φ, λ) and altitude over a reference ellipsoid. - Basic GPS segments – Control segment – List the components of the control segment - Describe the tasks of the Control segment – Space segment - Describe the satellite constellation concerning number of satellites, inclination of orbits, altitude and orbital period – State the different types of satellites – Describe the types and amounts of clocks in the satellites and the way to obtain the exact GPS time	

JAR-FCL REF NO	LEARNING OBJECTIVES	REMARKS
	- Identify the main task of the space segment – User segment – Identify the tasks of the User Segment – Interpret the 3 categories of GPS receiver architecture: multi channel, multiplex and sequential – State the meaning of the term "all in View" – Explain why multi channel receivers are preferred for aviation - State the current use of GPS – Navigation performance – Explain the following terms in relation to the horizontal 95% accuracy: - Selective Availability (S/A) – Standard Positioning Service (SPS) - Precision Positioning Service (PPS) – Explain the term integrity in relation to GPS receivers – RAIM (receiver autonomous integrity monitoring) - Integrity messages from earth stations or communication satellites – State the availability of GPS – Explain that the continuity is interrupted by switching to another satellite for the best GDOP – State the applications of GPS - Interpret the following Special Applications of GPS – precise time measurement and time interval measurement - altitude determination	

JAR-FCL REF NO	LEARNING OBJECTIVES	REMARKS
	– Define the following Future Applications of GPS – Enhanced Ground Proximity Warning System (EGPWS) - Automatic Dependent Surveillance Broadcast (ADS-B) – Satellite Constellation and Geometric Dilution of Precision – Define the following parameters relating to GPS orbital configuration: – orbit semi-major axis – satellite ground tracks up to 55°N/S – orbit satellite phasing – satellite visibility angle, – mask angle – satellite coverage – Explain how the actual position of the satellite is found – Illustrate the use of the (X, Y, Z) Earth Centred/ Earth Fixed co-ordinate system to define position vectors – Explain, in qualitative terms, how (x, y, z) co-ordinates can be transformed to co-ordinates (φ, λ, h) on the WGS-84 or on any other ellipsoid – Indicate the influence of the following perturbation factors – solar wind – gravitation of sun, moon and planets – Define the following terms: – Geometrical Dilution of Precision (GDOP)	

JAR-FCL REF NO	LEARNING OBJECTIVES	REMARKS
	– Position Dilution of Precision (PDOP) – Horizontal Dilution of Precision (HDOP) – Vertical Dilution of Precision (VDOP) – Time Dilution of Precision (TDOP) – User Equivalent Range Error (UERE) – Indicate the influence of elevation angle on dilution of precision – Explain the influence of dilution of precision on navigational accuracy – GPS Signals and Navigation Messages – Name the desired GPS navigation signal properties and signal specifications - Describe the GPS signals with reference to the following aspects: – GPS frequencies – signal characteristics: spread spectrum - signal structure, pseudo-random noise P and C/A codes, navigation message – Describe the level of the receiver Signal-to-Noise Ratio – Describe the navigation message and list the data in the 5 different subframes - Explain the relevance of ionospheric delays and indicate how their values are determined – Illustrate the relationship between the satellites and the control segment in respect of signal formation and transmission – GPS Generic Receiver Description – Name the basic elements of a GPS receiver – Identify, and give reasons for, the optimum antenna location.	

JAR-FCL REF NO	LEARNING OBJECTIVES	REMARKS

	– Name the primary information supplied by a GPS receiver:
	– Describe the presentation and interpretation of GPS data on a typical receiver type
	– Interpret GPS data presented on a control display unit
	– Name the requirements for GPS hardware and integration
	– Name the number of receiver channels required for various applications
	– Describe the cockpit equipment connected with GPS receivers
	– Describe in general terms the signal processing
	– Explain the 12.5 minutes to read the complete almanac with the parameters of all the satellites
	– In the algorithm to solve the position and receiver clock error from the pseudo range measurements, name the four unknown parameters.
	– Explain the following terms (in connection with the applications and the navigation algorithms)
	  – pseudo-range
	  – Doppler shift
	  – phase angle
	– Explain why, for accelerated satellite selection after a long suspension of use or a change in position,
	  – approximate position, time and date should be entered to shorten the search of the sky
	  – time to first fix may take up to 15 minutes
	– Describe the operation after a short suspension
	– Define the term 'Time to First Fix'
	– Signal Perturbations and Errors
		To be specified by JARFCL
		
		According JAA leaflet 3, TSO C129a, DO208, FAA AC's

JAR-FCL REF NO	**LEARNING OBJECTIVES**	REMARKS

	– Describe the method of Selective Availability (S/A) as used in the GPS system
	– State the intended aim of S/A
	– Name the errors produced in the receiver
	- Name the cause and the behaviour of ephemeris errors
	– Name the errors produced in the troposphere and in the ionosphere in relation to the elevation and mask angle
	– Indicate the influence of multipath propagation of GPS signals on navigational accuracy
	- Interpret the two methods used for the mitigation of multipath effects:
	  – special antenna design
	  - design of software in the receiver
	– Explain the effect of masking of satellites
	– Name the influence of satellite clock errors on the accuracy of GPS navigation
	- State possible interference sources for, and their effects on, a GPS C/A receiver
	– Differential GPS and Integrity Monitoring
	– Explain the elementary principle of Differential GPS
	– Name the major categories of Differential GPS
	– Explain why, for Differential GPS, a ground-based reference station is required in order to obtain differential corrections
	- Name the method of error correction used in DGPS (data message, data links)
	- State which errors can not be diminished by DGPS
	– Describe the characteristics of local area differential GPS (LADGPS) with reference to :	

JAR-FCL REF NO	LEARNING OBJECTIVES	REMARKS
	– differential corrections – integrity messages – reference station in the vicinity of e.g. an aerodrome - communication direct from ref. station to aircraft - Describe the characteristics of wide area differential GPS (WADGPS) with reference to : – differential corrections – integrity messages – more than one reference station in a nation or continent - communication from ref. stations via co-ordination centre to aircraft - Describe the characteristics of local area Augmentation system (LAAS) with reference to : – differential corrections – integrity messages – reference station in the vicinity of e.g. an aerodrome – communication direct from ref. station to aircraft – pseudolite(s) to improve the dilution of precision (DOP) – Describe the characteristics of Wide Area Augmentation (WAAS) with reference to : – differential corrections depending on lat./ long co-ordinates – integrity messages – reference stations in a wide area – communication from co-ordination centre station via INMARSAT satellites to aircraft	

JAR-FCL REF NO	LEARNING OBJECTIVES	REMARKS
	– INMARSAT satellites with nav. channel – Describe the characteristics of European Geostationary Navigation Overlay System (EGNOS) including reference to : – integrity messages – reference stations in the whole of Europe – communication from co-ordination centre station via INMARSAT satellite to aircraft – two INMARSAT satellites, Atlantic Ocean Region East and Indian Ocean Region, with nav. channel – Pseudolites – Describe the principle of the use of pseudolites – Name the data given by an integrated DGPS/Pseudolite installation: – Indicate the required aircraft antenna locations for GPS and for a pseudolite – Define 'Receiver Autonomous Integrity Monitoring' (RAIM) – State the minimum number of satellites necessary to perform RAIM – State the use of the failure detection and exclusion algorithm of RAIM – Integrated Navigation Systems using GPS - Define the term Multisensor System – GPS and INS Integration - State the advantages of GPS/INS integration with respect to redundancy and short and long term stability – Receiver Autonomous Integrity Monitoring (RAIM) Availability for GPS Augmented with Barometric Altimeter Aiding and Clock Coasting	

JAR-FCL REF NO	LEARNING OBJECTIVES	REMARKS
	- Identify the possible extension of the use of RAIM to include barometric altimeter aiding and clock coasting – Combination of GPS and GLONASS - Explain the requirements of Civil Aviation with respect to the combined use of GPS and GLONASS – GPS Navigation Applications – GPS Applications for Air Traffic Control – Interpret the application of GPS within the context of air traffic control for – oceanic control – enroute control – basic area navigation (cf. JAA Leaflet 2) – terminal control – non-precision approaches – precision approaches - surveillance - Name the required augmentations relating to the use of GPS for precision approaches – GPS Applications in Civil Aviation – Interpret the requirements for the use of GPS in Civil Aviation with respect to – dynamics – functionality: GPS position integrated with Inertial positions presented on a (EFIS) screen – accuracy: en-route GPS,	

JAR-FCL REF NO	**LEARNING OBJECTIVES**	REMARKS
	non precision approaches: DGPS, WADGPS or WAAS precision approaches LAAS and phase measuring – availability – reliability - integrity by differential stations - The following are to be described by LO's at a future date when the system architecture has been clarified and the use of GPS for automatic landings is accepted: – Automatic Approach and Landing with GPS – Precision Landing of Aircraft using Integrity Beacons – Future Implementations	