DOCUMENT
GSM-G-ATP.035

DOCUMENT TITLE
RADIO NAVIGATION

CHAPTER 5 – VHF OMNI-DIRECTIONAL RANGE (VOR)

Version 1.0
January 2013

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CHAPTER 5: VHF OMNIDIRECTIONAL RANGE (VOR)

VHF OMNIDIRECTIONAL RANGE (VOR)

VOR is an acronym for VHF Omni-Directional Range, also known as OMNI. Because it operates in the VHF band, it is not affected by many of the problems associated with ADF such static interference and night effect. It is similar to ADF in that is provides the bearing of the aircraft TO or FROM a transmitter at a known ground position. However whereas ADF equipment measures the direction of the radio wave when it arrives at the aircraft, the VOR airborne receiver decodes from the radio wave its direction when it left the ground transmitter.

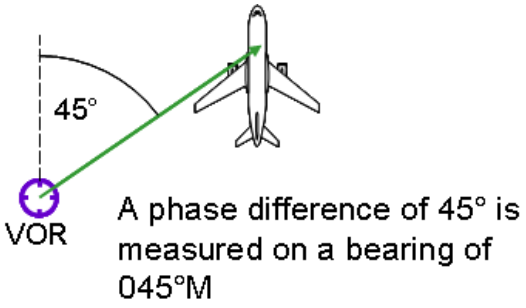
FREQUENCIES USED BY VOR

VOR operates on 160 separate frequencies between 108.0 and 117.95 MHz. Between 108 and 112 MHz, the available frequencies at 50 kHz spacing are shared between ILS Localizers and short-range terminal VORs (TVOR).

The even first decimals are allocated to VOR (e.g. 108.40, 108.45) and the odd first decimals to ILS (e.g. 108.10, 108.15). There are thus 40 ILS and 40 VOR channels between 108 and 112 MHz. Between 112 and 118 MHz, all the frequencies at 50 kHz spacing are allocated to VOR (e.g. 112.10, 112.15, 112.20 etc.) providing another 120 channels.

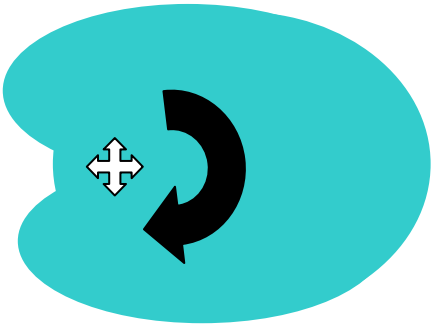
THE PRINCIPLE OF VOR

VOR operates on the principle of "bearing by phase comparison". The VOR transmission contains both frequency and amplitude modulated components and it is so arranged that the phase difference between these modulations is equal to the magnetic bearing of the aircraft from the VOR transmitter.



There are two types of VOR transmitters, Doppler VOR (DVOR) and conventional VOR. Both types obtain bearing by the principle that has been described in simple terms above. A more technical description of conventional VOR follows.

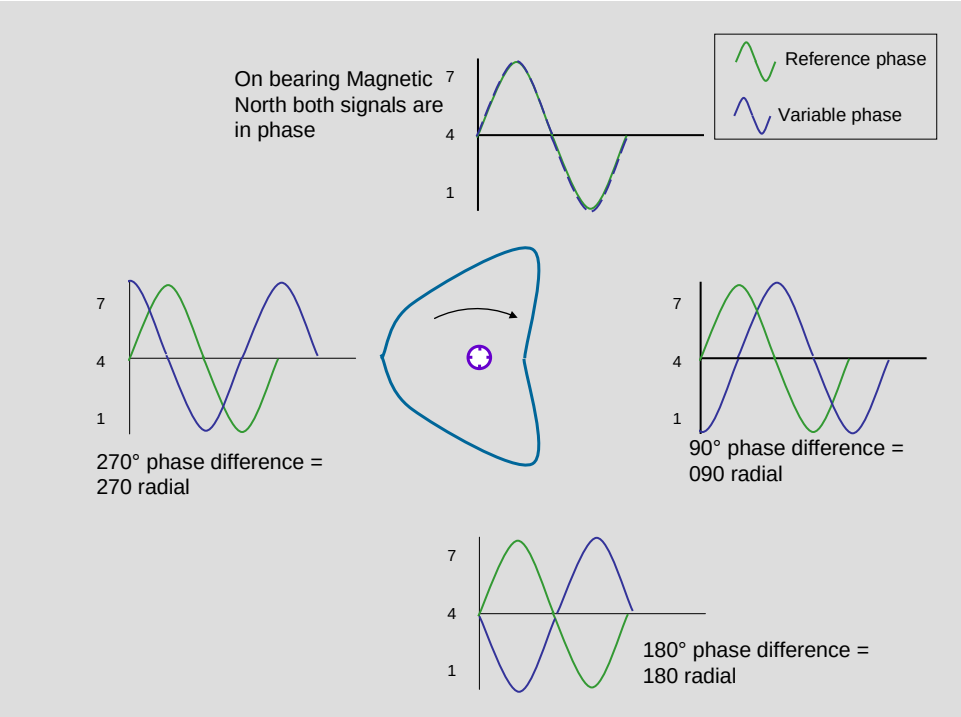
The transmitted signal from the VOR station consists of a VHF carrier frequency, amplitude modulated at a 30 Hz rate, and a sub-carrier, frequency modulated at a 30 Hz rate. The amplitude modulation is produced by rotating the transmitter's radiation pattern at a rate of 30Hz.



The polar diagram is described as a LIMACON. It is similar to a cardioid except that the amplitude does not fall to zero at the minimum value. Note also that the cardioid polar diagram of ADF refers to the receiver whereas the limacon of VOR refers to the transmission.

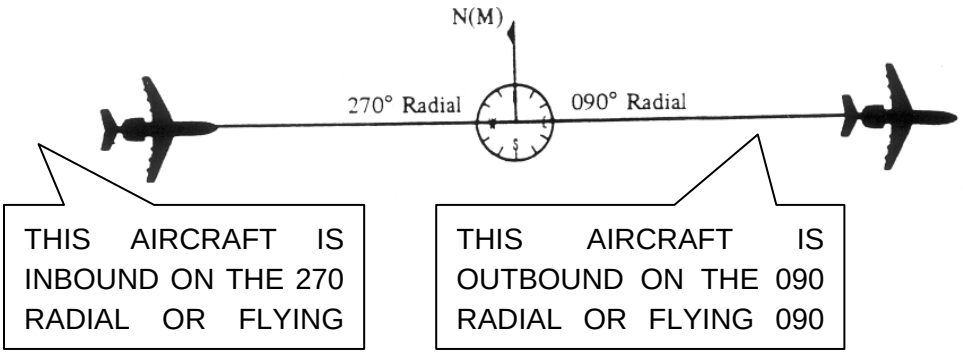
LIMACON POLAR DIAGRAM

It can be shown that the phase of the modulation of the rotating signal is different on different bearings and so it is referred to as the variphase signal.
The frequency modulations on the sub-carrier will be received at the same phase by aircraft equidistant from the transmitter and so provides the reference signal.



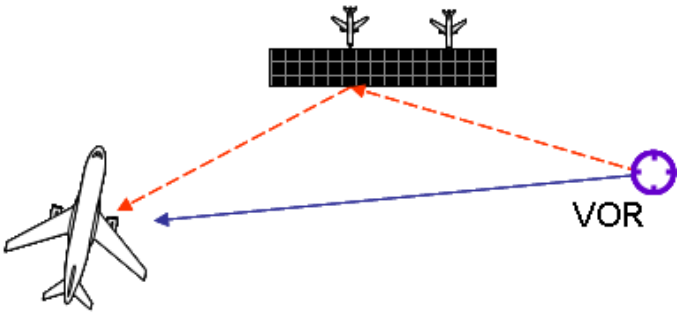
PHASE RELATIONSHIP OF THE FM AND AM COMPONENTS

The phase difference is equal to the magnetic direction of the radio wave as it leaves the transmitter. This magnetic direction in an outbound sense is termed a "radial". The VOR transmitter sends out radials in all directions.



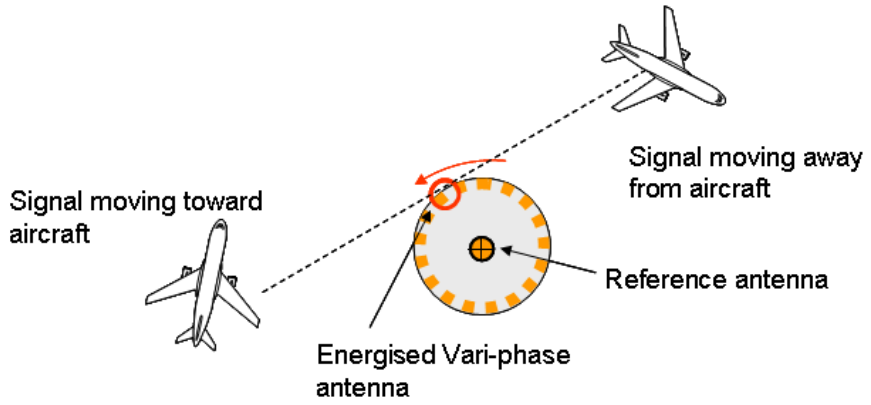
DOPPLER VOR

Conventional VOR is prone to inaccuracy due to reflections of the transmissions from terrain and man-made objects close to the transmitter. These reflections distort the limacon polar diagram so that amplitude does not rise and fall in the predicted manner as the radiation pattern rotates. The resulting error in the bearing that is measured is termed SITE ERROR.



Doppler VOR largely over comes this problem by reversing the roles of the AM and FM components. The amplitude modulated component is now the reference signal and as it is required to be the same on all bearings, the limacon polar diagram is no longer required. The FM component now becomes the vari-phase signal and to achieve different phase on different bearings, Doppler technique is applied.

The vari-phase signal is on the sub-carrier frequency and it is transmitted in turn by each one of up to 50 aerials sited in a circular pattern around the central aerial which transmits the AM reference signal.



Because the distance between the point of transmission and the aircraft receiver is increasing and decreasing as the aerials are switched, a Doppler shift is noted. The system appears to be rotating at 30 Hz and the Doppler induced FM has different phase on different bearings.

To summarize the differences between Doppler and Conventional VOR in terms of the purpose of the AM and FM components:

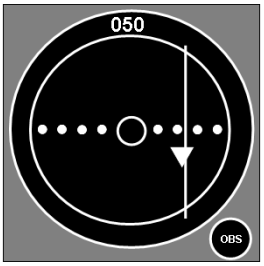
	AM	FM
Doppler VOR	REFERENCE	VARIPHASE
Conventional	VARIPHASE	REFERENCE

With Doppler VOR both site and propagation errors are reduced.

AIRBORNE EQUIPMENT

The airborne equipment for VOR consists of a receiver, a control unit, an aerial and an indicator. The receiver used for VOR may have the circuits required to process and decode ILS signals or separate receivers may be provided. The control unit allows the VHF Nav. frequency to be set which may be VOR or ILS and either may be paired with DME. A typical aerial is a vee type that receives ILS localizer as well as VOR signals. There are several types of indicators that can supply bearing information:

(i) the Omni Bearing Selector - Left/Right Indicator (OBS L/R)

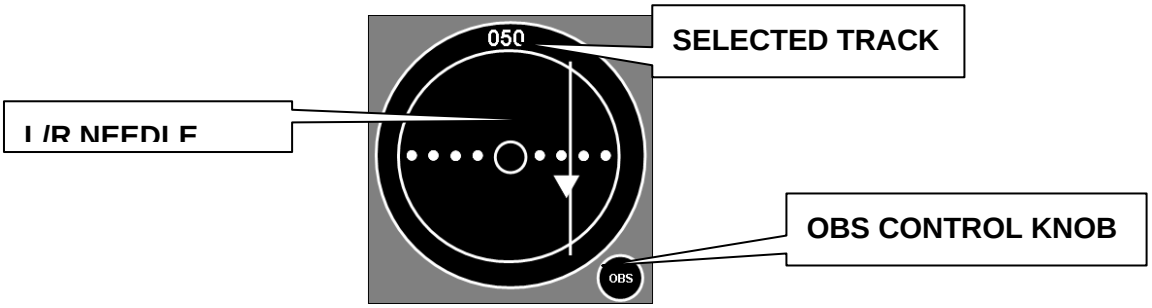


(ii) the Horizontal Situation Indicator (HSI)

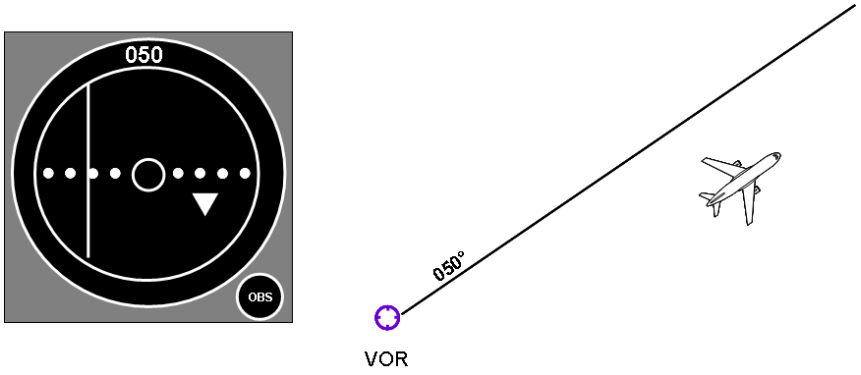
(iii) the Radio Magnetic Indicator (RMI)

USING THE OBS L/R INDICATOR

The following section describes the OBS-L/R indicator which consists of the OBS control knob, the TO/FROM indicator and the LEFT/RIGHT deviation indicator:

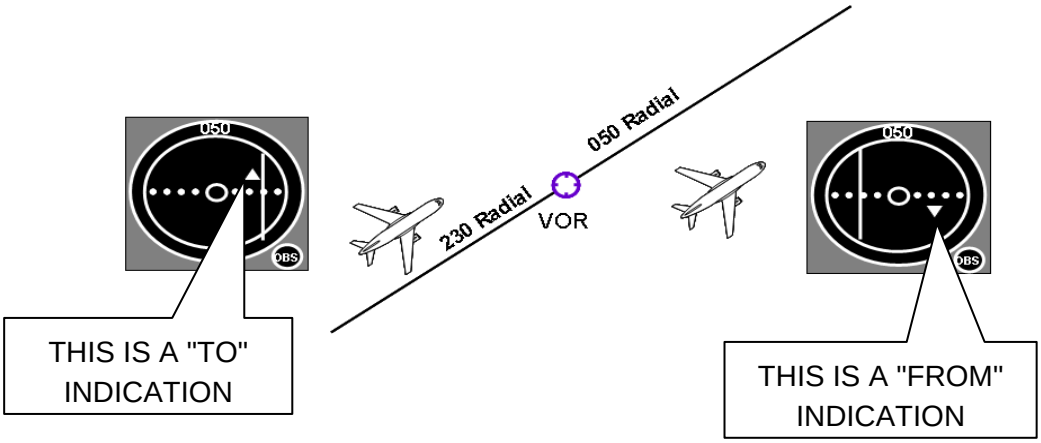


(i) The OBS CONTROL KNOB is used to select the magnetic track to fly to or from a VOR station If an aircraft is outbound from a VOR, the OBS should be set to the radial. If an aircraft is inbound, the OBS should be set to the reciprocal of the radial.

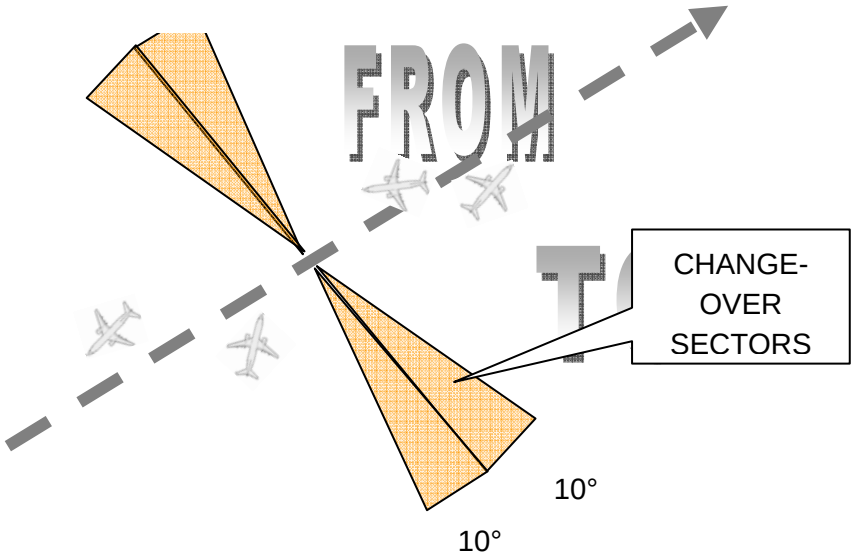


When the track is selected, the L/R needle will be displaced from its central position unless the aircraft is on the selected radial.

(ii) The TO/FROM indication depends upon the position of the aircraft in relation to the OBS radial and its reciprocal



If the selected radial is nearer to the aircraft's position, FROM will be displayed. If the reciprocal of the selected radial is nearer, TO will be displayed. Notice that the TO/FROM indication is independent of the aircraft's heading so that an aircraft approaching the VOR on the 070^{O} radial with OBS set to 070^{O} would have a FROM indication even though the aircraft is tracking to the VOR. If the OBS is set to the aircraft's magnetic track, TO will be displayed while tracking towards the VOR and FROM when tracking away. If the aircraft does not pass overhead, there may be a slow change from TO to FROM and both indications may be showing for some time.



(iii) The L/R deviation indicator shows the angular displacement of the aircraft from the OBS radial (or its reciprocal). Full scale deflection occurs when the aircraft is 10° or more away from OBS setting. If the aircraft is closer than 10^{O}, the needle will show the displacement with each dot worth 2^{O} on a 5 dot display or 5^{O} on a 2 dot display.

The diagram on the left illustrates a 5 dot display, the edge of the inner circle providing the first dot. The aircraft is 6^{O} (3 dots) right of the 070^{O} radial and so it is on the 076^{O} radial.

Provided the present heading roughly corresponds to the OBS setting, the pilot should follow the needle to regain track. In the example shown, the pilot should turn left. See worksheets at the end of the chapter for further examples of VOR orientation

FAILURE WARNING FLAG

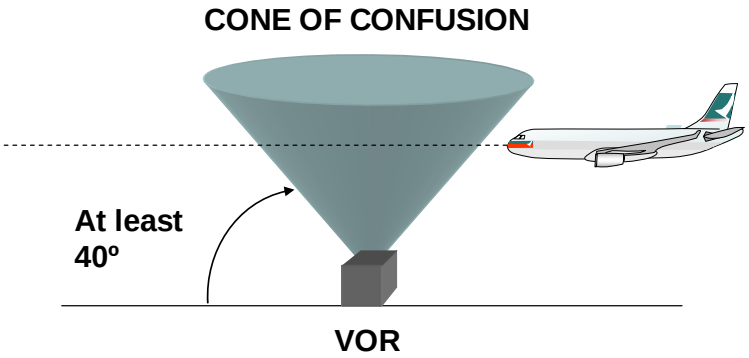
An OFF/NAV flag will appear on the indicator if any of the following occur:
failure of the aircraft's receiver
failure of the VOR transmitter
failure of the indicator
received signals are too weak or the aircraft is out of range

OBTAINING A BEARING

To obtain a bearing with the VOR.....
Switch ON
Check that the aircraft is within the Designated Operational Coverage (DOC) of the VOR
Set the frequency
Check the identification
Check that there is no OFF flag
Turn the OBS to centralize the L/R needle
- with FROM if radial is required

INDICATIONS OF STATION PASSAGE

There is a cone-shaped volume of space above the VOR transmitter in which signals will not be received.



This is called the "cone of confusion" because the VOR receiver temporarily loses track of the station.

The indications of station passage are as follows:

L/R needle swings from side to side

OFF flag may appear temporarily. Many VOR receivers have delay circuits to prevent this.

TO may show TO/FROM before changing to FROM.

RMI needle fluctuates then rotates

FACTORS AFFECTING VOR RANGE

1. **Transmitter Power**. Range is proportional to the square root of the power. En-route VORs have a power output of 200 watts for a range of 200 nm and Terminal VORs have a power output of 50 watts for a range of approximately 100 nm.

2. **Line of Sight Limitation**. As propagation is by direct waves, range is limited to the line of sight. This depends on aircraft height, transmitter height and the height of any intervening high ground. Range can be calculated using the formula:

$$\text{Range in nm} = 1.25\sqrt{\text{TX height}} + 1.25\sqrt{\text{RX height}}$$

Note: Heights are in feet AMSL.

3. **Designated Operational Coverage (DOC)**. The same frequency may be allocated to Two VORs in a given geographical region and this could lead to mutual interference. This interference may result in.....

   (a) Garbled identification

(b) Bearing or range errors
(c) Inability to acquire the nav. signal

(d) Acquiring the wrong signal

To prevent interference, pilots must not attempt to use a VOR outside of the published DOC which is specified as a maximum range and altitude.

Note that the DOC of a particular VOR might be considerably less than its line-of-sight range calculated at 2. above.

4. **Nature of Terrain**. The AIP warns pilots of site and propagation errors that are known to exist. The terrain can therefore limit the range at which the VOR is used in these directions.

VOR MONITOR

Transmissions from VOR stations are monitored for accuracy and signal strength. The monitor will either remove the identification and navigation components from the transmission or switch off the radiation altogether in the event of any of the following:

a). a change in bearing of greater than 1^{O}.

b). a reduction in signal strength of more than 15%.

c). failure of the monitor itself.

TEST VOR (VOT)

At some locations a VOR will provide a test signal providing phase locked AM and FM components. The resulting zero phase difference will cause the VOR receiver to indicate either 000° FROM or 180° TO. The accuracy of the test bearing should be ± 4°.

IDENTIFICATION

VORs normally transmit a 3-letter Morse code group (1020 Hz AM) at least once every 10 seconds. Identification may also be in speech e.g. "This is Frankfurt VOR" followed by a 3-letter Morse group. The VOR may also carry the ATIS broadcast.

SOURCES OF VOR ERROR

1. Site Error. As previously described, obstacles, which may be man-made or natural, in the vicinity of the transmitter cause reflections of the signal resulting in errors. These errors are reduced in Doppler VOR and in any case, should not exceed 1^{O} because of the monitor.

2. Propagation Errors. Irregular terrain between the transmitter and the aircraft may cause further anomalies resulting in oscillations of the VOR needle. Slow oscillations are described as "bends" and rapid oscillations as "scalloping".

3. Airborne Equipment Errors. The phase relationship between the FM and AM components of transmission must be accurately measured to establish the magnetic bearing. Minimum specifications are defined for VOR receivers and so errors should be small.

4. Interference Errors. Pilots are warned that using a VOR below the line of sight or outside its DOC can lead to errors in navigation.

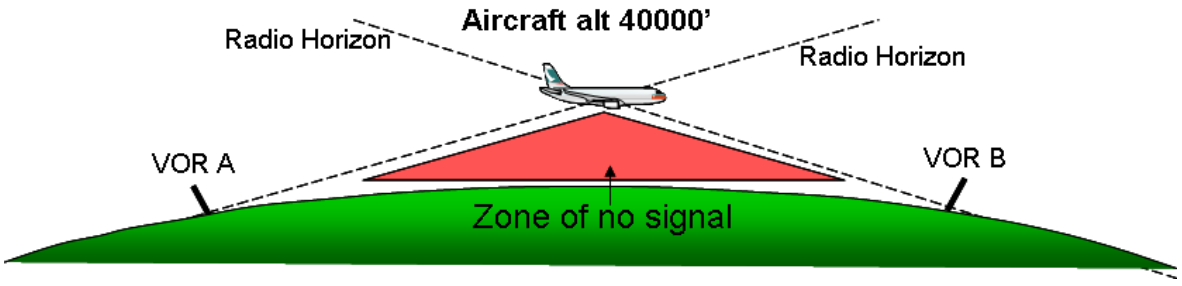
5. Pilotage Error. When a approaching the VOR station the distance between the radials decrease as the radials get closer together. Therefore the pilot may have difficulty tracking on the radial as minor heading deviations will cause movement of the CDI.

OVERALL ACCURACY OF VOR

The specified accuracy of the information displayed is $\pm 5^{O}$ in normal circumstances with a "worst case" accuracy of $\pm\ 7^{1}/_{2}{}^{O}$. In good conditions accuracy in the order of 1-2° is usually attainable

CALCULATING THE DISTANCE BETWEEN VORS (SOME EXAMPLES)

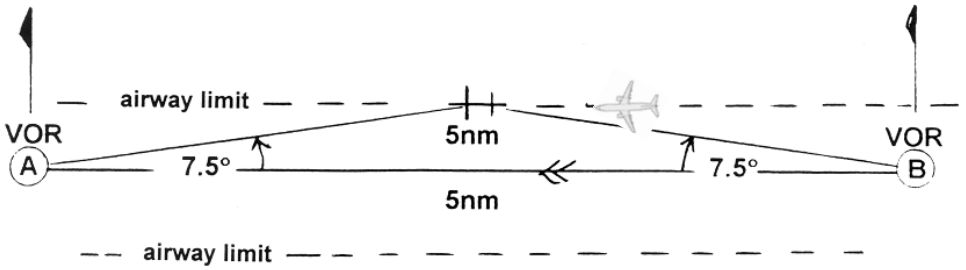
1. To avoid interference for an aircraft at 40000', both VORs at mean sea level



$$\text{Line of sight range} = 1.25\sqrt{4000} = 250\ \text{nm}$$

VOR A and VOR B must be more than 500nm apart if they operate on the same frequency.

2. To ensure that aircraft remain within an airway (width 10nm) if VOR radials defining the airway have accuracy $\pm$ $7^1/_2°$



If max distance of track at mid-point is 5nm, distance to midpoint can be found by the 1-in-60 rule.

$$\frac{\text{ANGLE}}{60} = \frac{\text{DIST OFF}}{\text{DIST ALONG}}$$

$$\text{DIST ALONG} = \frac{\text{DIST OFF x 60}}{\text{ANGLE}}$$

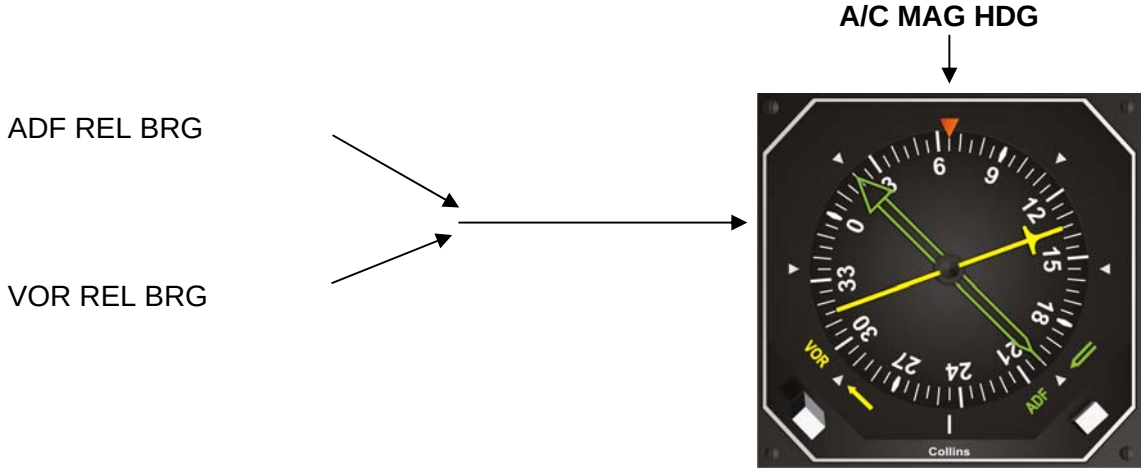
$$= \frac{5 \times 60}{7\,{}^1/_2}$$

$$= 40\ \text{nm}$$

Maximum distance between VOR A and VOR B is 80nm.

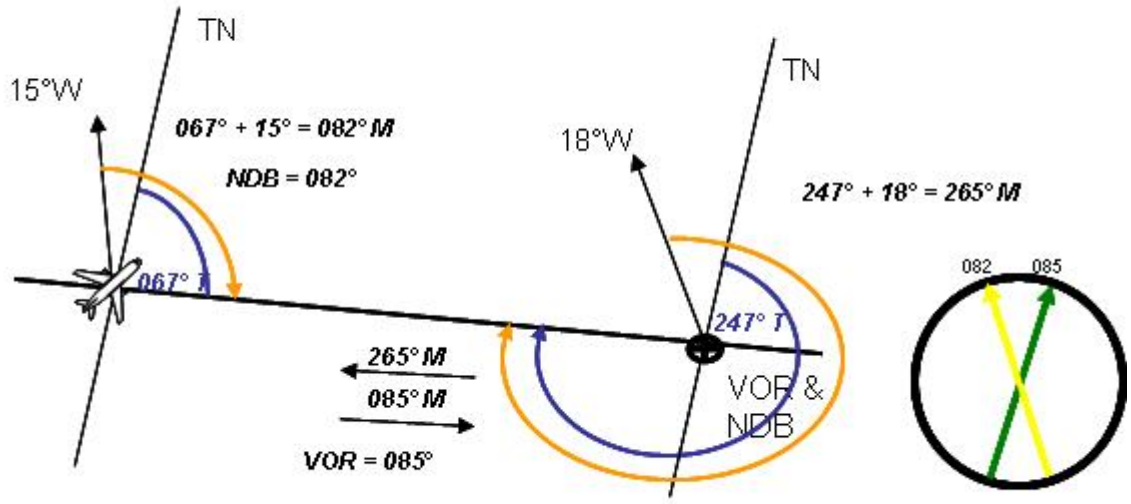
RADIO MAGNETIC INDICATOR (RMI)

The RMI is an alternative indicator for VOR and ADF. For both VOR and ADF bearings, the orientation of the pointer is determined by relative bearing but the reading of the pointer when taken against the compass card is magnetic bearing to the aid (QDM). The compass card rotates to show magnetic heading against the index at the top. As the card must be driven, the RMI requires an electrical input of heading such as that provided by a gyro-magnetic compass.



ADF measures relative bearing but VOR measures phase difference which is equal to QDR (Magnetic Bearing From). VOR relative bearing for the pointer is found by the use of a differential synchro which subtracts aircraft magnetic heading from QDM (reciprocal of the phase difference).
It is of theoretical interest to consider that if the pointers were selected to an NDB and a VOR at the same site, they would not exactly coincide on the RMI even if the bearings were totally accurate.

A VOR and NDB are located on an aerodrome (variation 18°W). An aeroplane flying where the variation is 15°W is on a bearing of 247°T from the aerodrome. The VOR and ADF indications on a twin pointer RMI would be:



This difference results from the different principles by which ADF and VOR operate. In effect, the ADF bearing has been measured at the aircraft and the VOR bearing has been measured at the VOR station. Because of convergency and differences in variation, ADF and VOR magnetic bearings displayed on the RMI would not be the same, even when the transmitters are co-located. The above example takes into account differences in variation only.

EFFECT OF COMPASS ERROR ON THE RMI

A gross compass error would affect ADF and VOR bearings differently.

	ADF	VOR
Relative Bearing	CORRECT	WRONG
Magnetic Bearing	WRONG	CORRECT

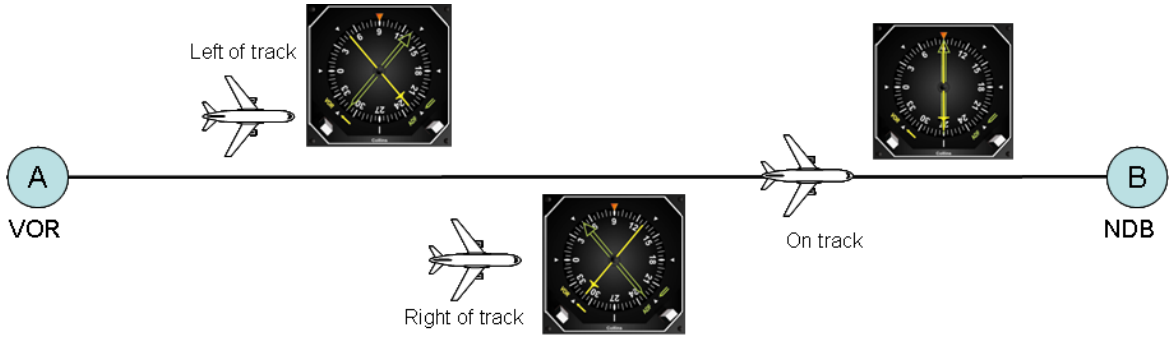
This difference arises because of the different processing required to obtain relative bearing by ADF and VOR. See worksheets for further examples of compass error and RMIs

ADF AND VOR SELECTIONS

If the aircraft is fitted with twin ADF and twin VOR, either or both pointers can be selected to each aid. Most current airline aircraft are fitted with an RMI.

TRACKING BY RMI

If the aircraft is on track between NDBs or VORs, the pointers on the RMI will be aligned. It can be readily seen from the RMI on which side of track the aircraft is located.



See Worksheet: 'RMI/VOR Orientation' at the end of the chapter for further examples of RMI orientation

WORKSHEET - VOR

1. Which of the following is true of CONVENTIONAL VOR?

   (a) The AM and FM components are on the same VHF frequency but have different modulation rates.
   (b) The AM and FM components are on different VHF frequencies but have the same modulation rate.
   (c) The FM component is a modulation of the 9960 Hz sub-carrier.
   (d) The AM component is produced by rotating a limacon pattern at 30 rpm.

2. Which of the following is a VOR frequency?

   (a) 113.35 MHz
   (b) 118.20 MHz
   (c) 109.10 MHz
   (d) 108.30 MHz

3. Which of the following is true of DOPPLER VOR?

   (a) Only the reference signal is FM
   (b) Only the vari-phase signal is FM
   (c) Both reference and vari-phase signals are FM by Doppler technique
   (d) Both reference and vari-phase signals are AM by Doppler technique

4. En-route VORs have a range of :-

   (a) 200 nm
   (b) 100 nm
   (c) 50 nm
   (d) 10-25 nm

5. The OFF flag will appear on the VOR indicator if:-

   (a) the RX fails but not if the TX fails
   (b) the TX fails but not if the RX fails
   (c) if either the TX or the RX fails
   (d) only when the airborne equipment is switched off.

6. The principle of VOR is bearing by:-

(a) phase comparison
(b) modulation comparison
(c) polarity comparison
(d) frequency comparison

7. Attempting to use a VOR outside of its published range could result in
(I) bearing errors (ii) garbled identification (iii) acquisition of the wrong signal

(a) (i) and (ii) only are true
(b) (i) and (iii) only are true
(c) (ii) and (iii) only are true
(d) all are true

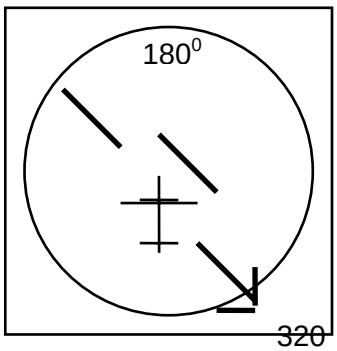
8. What phase difference would be measured by an aircraft located at a position where the bearing to the VOR is 146^0T? Variation at the aircraft and at the VOR is 6^0W.

(a) 332^0
(b) 320^0
(c) 140^0
(d) 152^0

9. An aircraft is on a bearing of 230^0 M from a VOR. If the expected drift is 10^0 left, what OBS selection should be made to track directly to the VOR from the aircraft's present position?

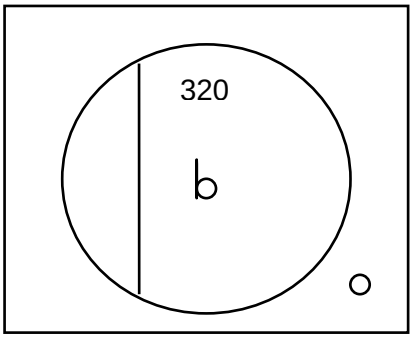
(a) 230^o
(b) 240^0
(c) 050^0
(d) 060^0

10.

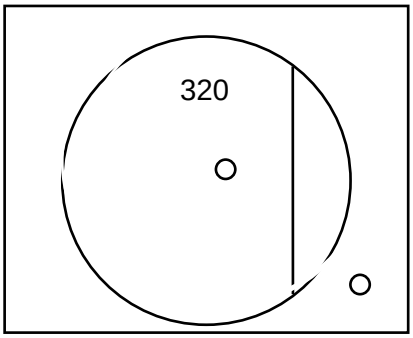


What is the equivalent OBS L-R display?

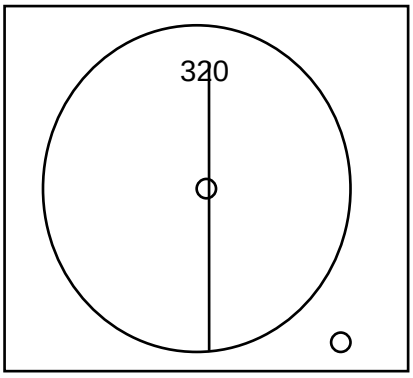
(a)



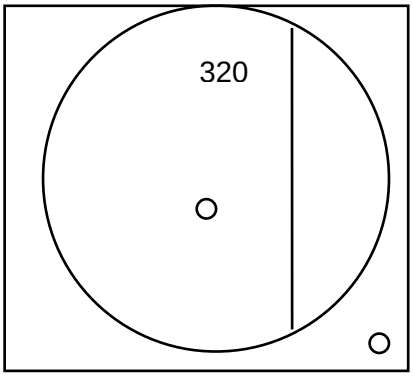
(c)



(b)



(d)

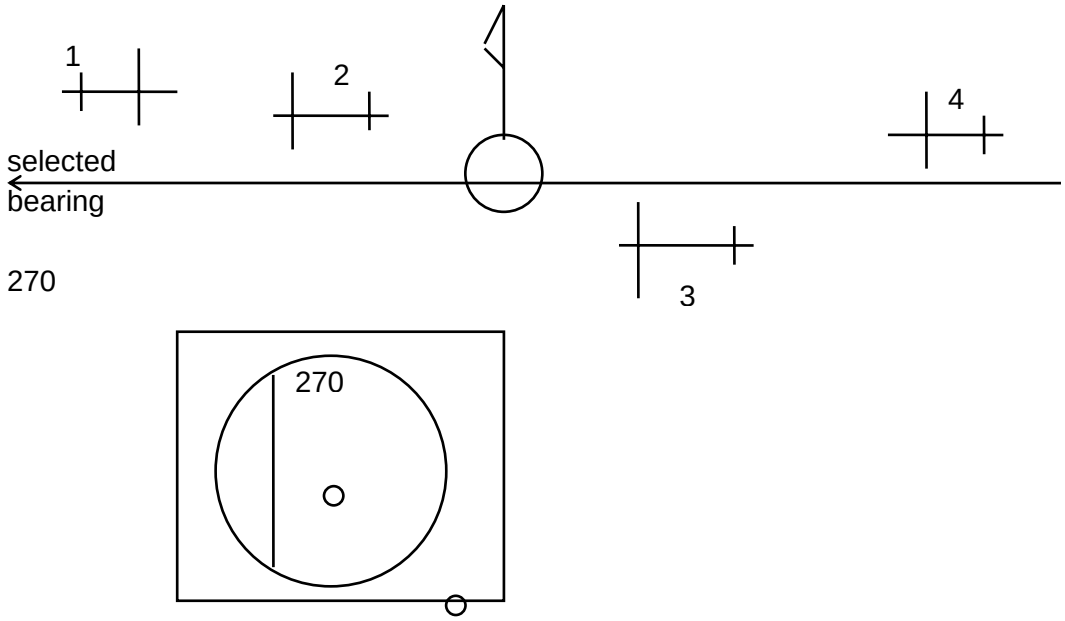


11. VOR transmissions have a wavelength of approximately _____ and have the ICAO designator _____.

	WAVELENGTH	DESIGNATOR
(a)	30cm	A8W
(b)	3 metres	A9W
(c)	3cm	A8W

(d) .3 km A9W

12. The diagram below shows four aircraft in relation to a VOR.



Which aircraft position(s) correspond to the OBS/L-R display?

(a) 4 only
(b) 3 only
(c) 2 only
(d) 1 and 2

13. The effective range of a VOR varies _____

(a) by day and night and also with aircraft height
(b) with aircraft height but not by day and night
(c) neither with aircraft height nor by day and night
(d) by day and night but not with aircraft height.

14. The overall accuracy of VOR bearings when displayed is .....

(a) $\pm 1^0$ and this is guaranteed by the monitor.
(b) $\pm 2^0$
(c) $\pm 3^0$
(d) $\pm 5^0$

15. The reference signal of conventional VOR is produced by frequency modulation of the _____ and its polar diagram is in the shape of a _____ .

(a)	VHF carrier wave	limacon
(b)	sub-carrier	circle
(c)	sub-carrier	figure-of-eight
(d)	VHF carrier wave	cardiod

16. The limacon polar diagram is the result of:

(a) the modulation of the 9960 Hz sub-carrier.
(b) the rotation of the omni-directional continuous wave transmission.
(c) the rotation of the directional (figure-of-eight) transmission.
(d) the combination of the reference and directional signals.

17. In a Doppler VOR (DVOR) system, the reference signal is transmitted from _____ and it is _____ modulated.

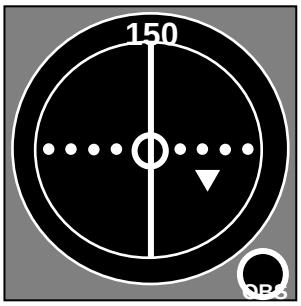
(a)	a circle of aerials	frequency
(b)	a central aerial	amplitude
(c)	a central aerial	frequency
(d)	a circle of aerials	amplitude

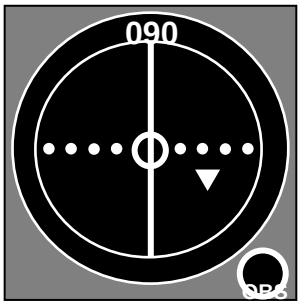
VOR/HSI ORIENTATION PROBLEMS

EXERCISE 1

From the information on the following OBS displays, identify which radial you are on.

1. 

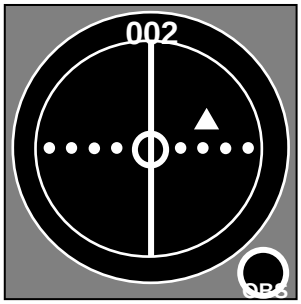
2. 

3. 

4. 

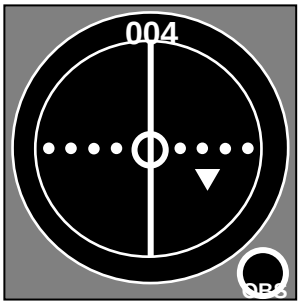
5. 

6. 

7. 

8. 

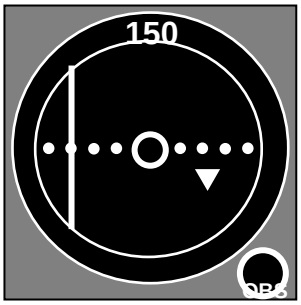
9. 

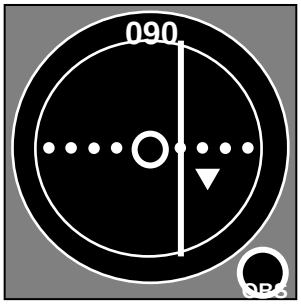
10. 

EXERCISE 2

From the information on the following OBS displays, identify which radial you are on.

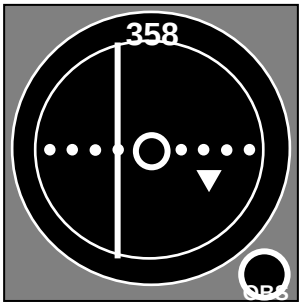
1. 

2. 

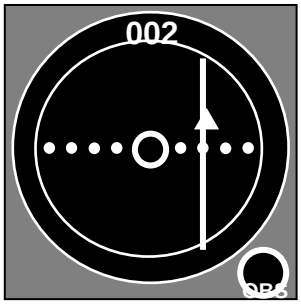
3. 

4. 

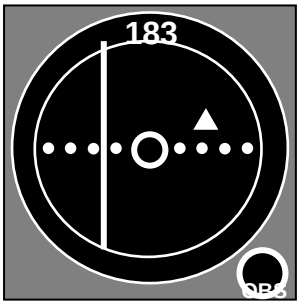
5. 

6. 

7.

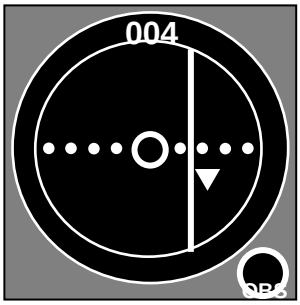


8.



9.

10.



EXERCISE 3

In the following situations determine:

1. What radial you are on
2. Which direction do you need to turn to centre the CDI?

1.

HDG: 340°M

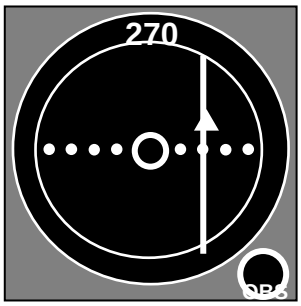
2.

HDG: 315°M

3.

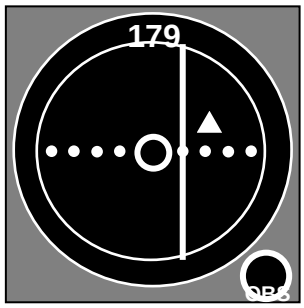
HDG: 230°M

4.



HDG: 090°M

5.



HDG: 005°M

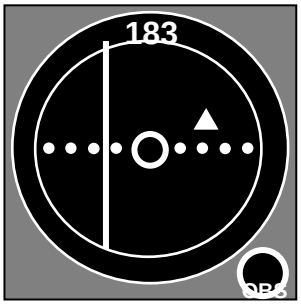
6.

HDG: 250°M

7.

HDG: 168°M

8.



HDG: 003°M

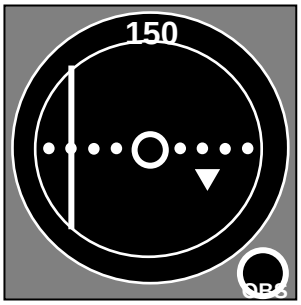
EXERCISE 4

From the information shown on the following VOR displays identify which radial you are on. To help with orientation sketch the aircraft's location in relation to the selected radial.

1.

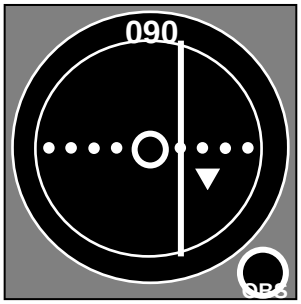
HDG: 252°M

2.



HDG: 163°M

3.

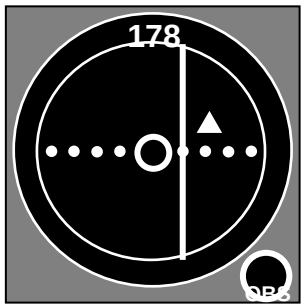


HDG: 270°M

4.

HDG: 311°M

5.

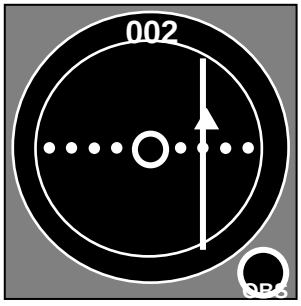


HDG: 358°M

6.

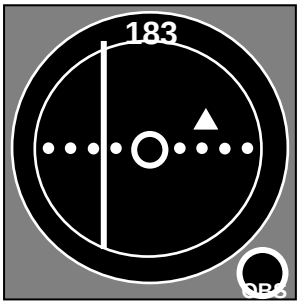
HDG: 005°M

7.



HDG: 183°M

8.

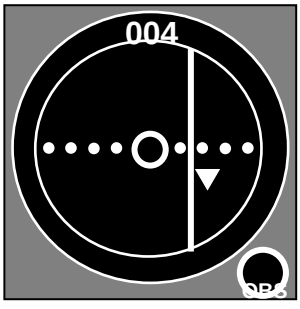


HDG: 004°M

9.

HDG: 171°M

10.

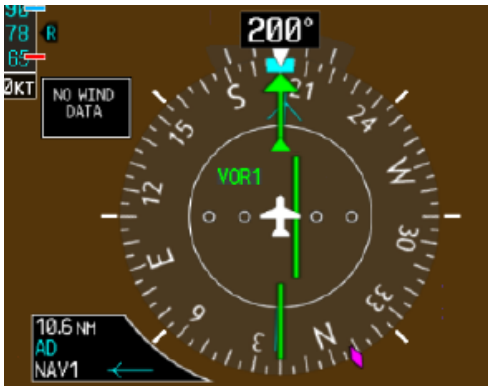


HDG: 004°M

EXERCISE 5

Applying the VOR orientation skills from above use the following HSI displays to determine the radial on which the aircraft is located. Also draw a diagram to illustrate the aircraft's orientation in relation to the station.

Question 1



Question 2

RMI DEVIATION

The RMI shown below has a deviation of 5°E. The VOR and ADF have been correctly tuned and identified.

Which information presented in the tables is correct given the current RMI indications

1.

	HDG	VOR QDM	RELATIVE BEARING TO NDB
A)	125°M	110°M	230°
B)	125°M	115°M	350°
C)	115°M	110°M	355°
D)	115°M	105°M	355°

2.

	HDG	VOR RADIAL	NDB QDR
A)	125°M	290°M	170°
B)	125°M	290°M	175°
C)	115°M	285°M	165°
D)	115°M	105°M	175°

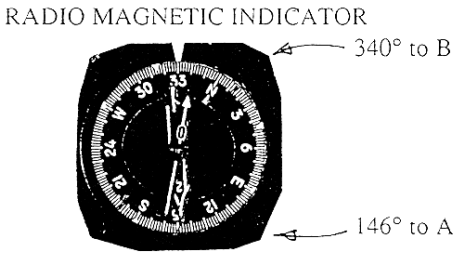
3.

	HDG	RELATIVE BEARING TO VOR	NDB QDM
A)	115°M	345°M	230°
B)	125°M	350°M	350°
C)	125°M	345°M	355°
D)	115°M	335°M	355°

RMI ORIENTATION

Radio Navigation - Interpreting RMI Displays

1. The RMI display shown below was obtained by an aircraft enroute between VOR A and VOR B. The direct track between A and B measures 332°M. The aircraft has maintained its present heading of 330°M since passing over A.

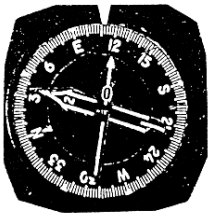


What should be the new heading to track direct to VOR B?

a. 344.
b. 316.
c. 340.
d. 336.

2. You are heading 112°M towards NDB X along the direct track which measures 120°M. You are required to report abeam VOR Y which is to the left of track. The RMI display below shows the aircraft approaching the abeam position.

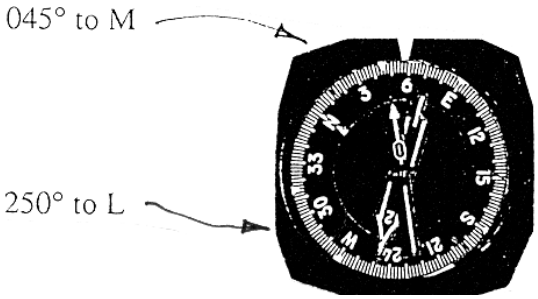
RADIO MAGNETIC INDICATOR



At what RMI reading to VOR Y will you make your transmission?

a. 012.
b. 022.
c. 030.
d. 040.

3. You have maintained heading 058°M since passing overhead VOR L. The bearings to VOR L and VOR M are displayed on the RMI below.

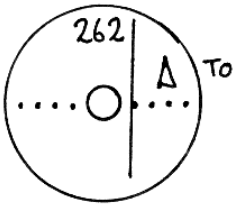


What should be the new heading to track direct to VOR M?

a. 083.
b. 045.
c. 035.
d. 033.

RADIO NAVIGATION - PRACTICE QUESTIONS

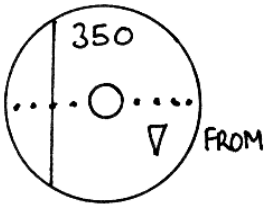
1.



Which radial is the aircraft on?

a. 266.
b. 258.
c. 086.
d. 078.

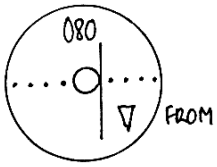
2.



Which radial is the aircraft on?

a. 344.
b. 164.
c. 174.
d. 356.

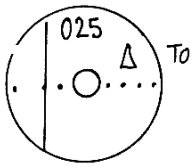
3.



Which radial is the aircraft on?

a. 078.
b. 082.
c. 258.
d. 262.

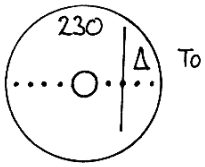
4.



What is the magnetic bearing to the station?

a. 019.
b. 031.
c. 199.
d. 211.

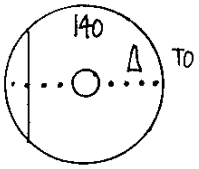
5.



What is the magnetic bearing to the station?

a. 224.
b. 044.
c. 236.
d. 056.

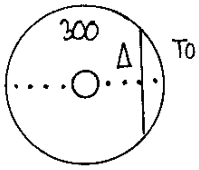
6.



Which radial is the aircraft on?

a. 148.
b. 132.
c. 328.
d. 312.

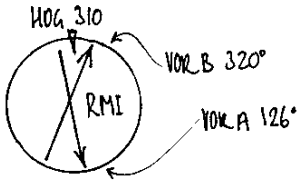
7.



What is the magnetic bearing to the station?

a. 292.
b. 308.
c. 112.
d. 128.

8. Aircraft is tracking between VOR A and VOR B .

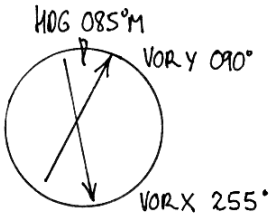


What is the new heading° M to track direct to B?

a. 324
b. 296
c. 320
d. 306

9. Radio Magnetic Indicator

Aircraft is tracking between VOR X and VOR Y.

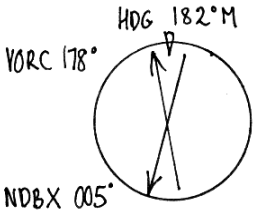


What is the new heading to track direct to Y?

a. 070°M.
b. 100°M.
c. 095°M.
d. 075°M.

10. Radio Magnetic Indicator

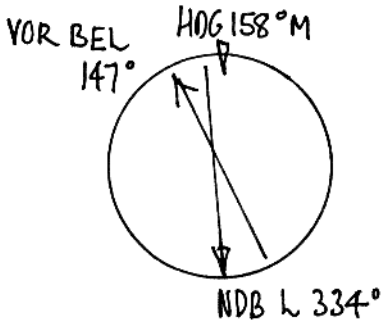
Aircraft is tracking between NDB X to VOR C.



What is the new heading to track direct to C?

a. 189°M.
b. 178°M.
c. 180°M.
d. 175°M.

11. Radio Magnetic Indicator



Aircraft is tracking between NDB L and VOR BEL. What is the new heading to track direct to BEL?

a. 165°M.
b. 151°M.
c. 147°M.
d. 155°M.

12. An aircraft is flying between NDB R to VOR C along track 096°M. Heading of 084°M has not been changed since the aircraft flew over NDB R.

The following bearings are obtained :
NDB R 188° Relative.
VOR C 281 Radial.

What is the new heading to track direct to C?

a. 093M.
b. 075M.
c. 096M.
d. 264M.

13. An aircraft is flying between NDB A and VOR Y. Heading is maintained constant on 140°M. The direct track AY is 135°M.

The following bearings are obtained :
NDB A 170° Relative
VOR Y RMI reads 138°

What heading should the aircraft fly to track direct from its present position to VOR Y?

a. 132°M.
b. 170°M.
c. 148°M.
d. 140°M.

14. An aircraft is flying between VOR A and NDB U. Heading is maintained constant on 250°M. The direct track AU is 240°M.

The following bearings are obtained :
VOR A RMI reads 066°
NDB U 344°Relative

What heading should the aircraft fly to track direct from its present position to NDB U?

a. 244°M.
b. 238°M.
c. 262°M.
d. 066°M.

15. An aircraft is flying between VOR M to NDB T. Heading is maintained constant on 350°M. The direct track MT is 360°M.

The following bearings are obtained :
VOR M 003 Radial
NDB T RMI reads 355°

What heading should the aircraft fly to track direct from its present position to T?

a. 358°M.
b. 345°M.
c. 347°M.
d. 342°M.

16. An aircraft is flying between VOR X and NDB RAY. Heading is maintained constant on 080°M. The direct track X to RAY is 090°M.

The following bearings are obtained :
VOR X RMI reads 274° NDB RAY 006° Relative

What heading should the aircraft fly to track direct from its present position to Y?

a. 072°M.
b. 086°M.
c. 090°M.
d. 084°M.