DOCUMENT

GSM-AUS-CPL.028

DOCUMENT TITLE

CPL NAVIGATION 2 (AUSTRALIA)

CHAPTER 6 – VHF OMNI-DIRECTIONAL RANGE (VOR)

Version 2.1

November 2017

CONTENTS .... PAGE

VHF OMNI-DIRECTIONAL RANGE (VOR)

6.1 Introduction

The VOR was developed in the USA during the years after World War Two. It was a replacement for the then current radio range beacon technology which operated on the LF/MF frequency bands.

VOR stands for VHF Omni-directional Range and its use of the VHF frequency band gave it a reliability that earned it the official ICAO standard for a short range navigation aid in 1949.

6.2 Description and Purpose

VOR transmissions represent bearings radiating out from the station. 360 bearing or tracks are able to be measured by the aircraft's equipment. These tracks are known as radials. The use of the VHF band means that the transmissions are not affected by many of the problems associated with the ADF such as static interference and night effect. It can therefore be used at any time of day.

Indications are in terms of deviation to the left or right from a selected track (radial). Information may also be fed to an RMI (Radio Magnetic Indicator) to give QDMs and QDRs.

The VOR can be frequency paired with DME (Distance Measuring Equipment). Thus, a range (distance) as well as a radial (magnetic bearing from the station) is provided, and an instantaneous fix can be plotted on a chart or aircraft position reported to ATC for radar identification and traffic separation purposes.

Frequency pairing means that the DME frequency is automatically tuned as the VOR frequency is being selected, reducing cockpit workload.

The VOR ground station transmits on a specific VHF frequency between 108.00 and 117.95 MHz and is an A9W type of emission. It shares the frequency range 108.00 MHz to 112.00 MHz with the Instrument Landing System (ILS). The ILS uses all the odd decimal frequencies within this range, e.g. 109.10 MHz and the VOR the even decimal frequencies. From 112.00 MHz to 117.95 MHz is reserved solely for VOR use. VHF communications use the frequency range starting from 118.00 MHz onwards.

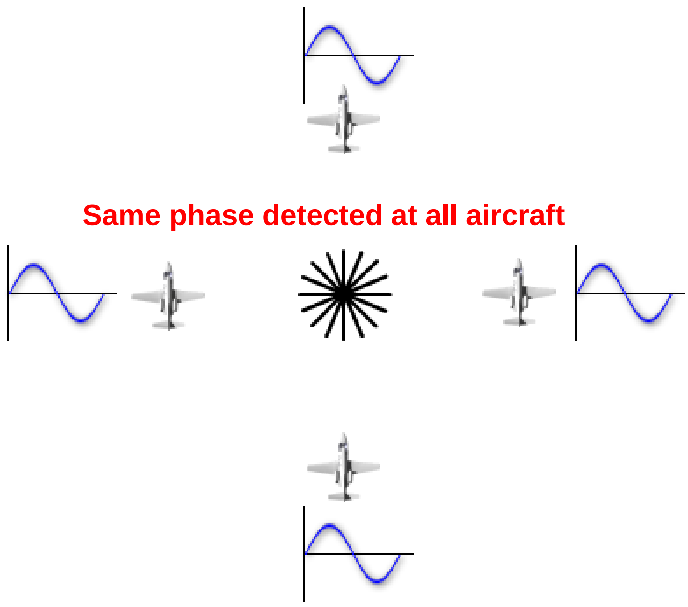
6.3 Operating Principles

The VOR's principle of operation is bearing measurement by phase comparison. The ground station transmits two separate signals; a reference signal and a variable phase (also called the directional) signal. The reference signal is an omni-directional transmission and the variable phase signal is directional. The receiver equipment in the aircraft measures the difference in phase between the two signals and equates this to a magnetic bearing from the station (radial), i.e. a phase difference of 50° would place the aircraft on the 050° radial (R050).

6.3.1 Reference Signal

The reference signal is a combination of the VHF carrier signal at the allocated transmission frequency which is then impressed upon a sub-carrier wave, of 9960 Hz, which has been frequency modulated at 30 Hz.

As it is an omni-directional signal, it has a circular polar diagram. Therefore all bearings received by an aircraft at a given distance from the beacon will have the same phase.

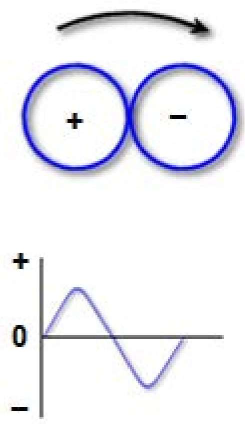


The aircraft's receiver measures phase difference by using the 30 Hz component of the transmission as the datum to measure the variable phase signal against.

6.3.2 Variable Phase or Directional Signal

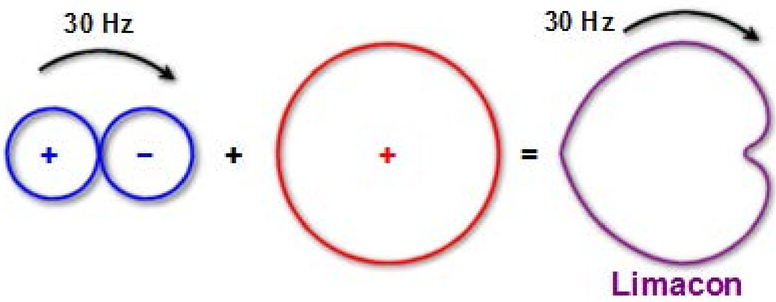
The variable phase signal is transmitted on the VOR station allocated carrier frequency. The signal is fed from the transmitter into a horizontal dipole antenna. This antenna produces a figure of eight polar diagram. The antenna is then rotated at a speed of 1800 rpm (30 revolutions per second) producing a rotating figure eight polar diagram.

The rotation of the aerial at a rate of 30 times per second amplitude modulates the signal at a frequency of 30Hz. The VOR transmitter is calibrated so that zero phase difference occurs on Magnetic North. Therefore the receiver equipment in the aircraft can measure the difference in phase between the two signals and equate this to a radial, i.e. a phase difference of 50° would place the aircraft on the 050° radial. That is a magnetic track radiating out from the station in the direction of 050° magnetic towards the aircraft, relative to the station's Magnetic North reference.



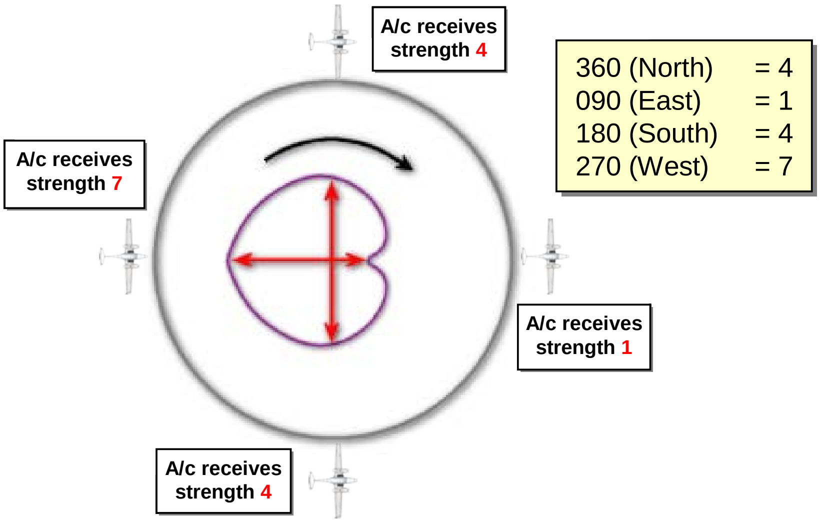
6.3.3 Determining the Phase Difference

The combination of the reference and variable phase signals produce a rotating polar diagram similar in shape to the cardioid that is called a **Limacon**.

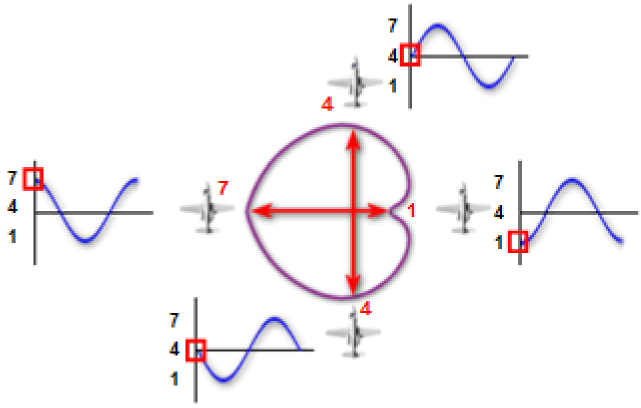


A Limacon is different from a cardioid because it does not have a null position. It has a position of minimum field strength instead.

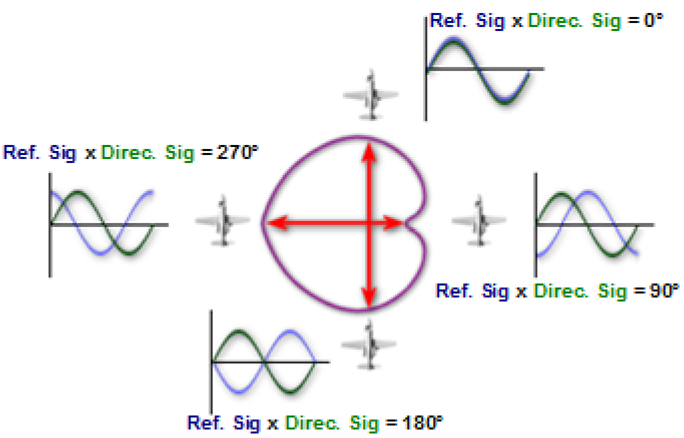
The field strength of both signals is combined at the transmitter and is then electronically adjusted to produce a power relationship between the two signals in the ratio of 4:1:4:7 on the four cardinal points. Refer to the diagram on the next page.



The directional characteristic of the transmission is revealed, when the amplitudes of both signals are plotted on a time axis.



The two signals are plotted against the four cardinal points and the variation in phase between the **reference signal**, and the **directional signal** can be seen.



The phase difference in degrees directly relates to the magnetic bearing from the VOR as measured from the station's Magnetic North reference.

6.4 Range and Accuracy

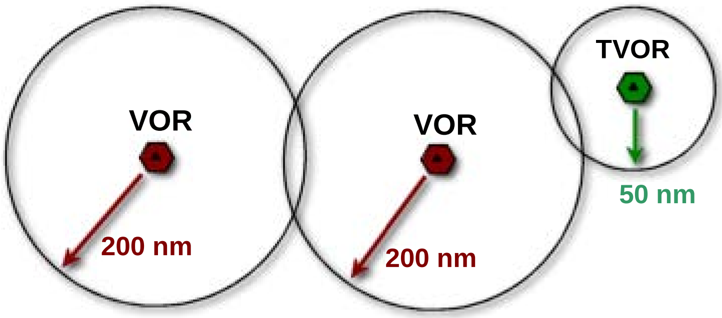
6.4.1 Factors Affecting Range

The following factors affect the transmission range of the VOR:

- Transmission power
- Transmitter and aircraft height
- Protection range and altitude

6.4.1.1 <u>Transmission Power</u>

Range is proportional to the square root of the transmitter power. En-route VORs with a power output of 200 watts can achieve a range of approximately 200 nm.



Terminal VORs (TVORs) have a power output of 50 watts, for a range of approximately 50 nm. (There are no TVORs operating in Australia).

6.4.1.2 <u>Transmitter and Aircraft Height</u>

VOR transmissions are propagated via Direct Waves. Therefore, the maximum theoretical range is limited to the line of sight distance between the transmitter and receiver.

Theoretical range can be calculated using the formula:

$$\text{Max Range (nm)} = 1.25\sqrt{H_T} + 1.25\sqrt{H_R}$$

Where:

H_T = Height of transmitter in feet (AMSL)

H_R = Height of receiver in feet (AMSL)

Example: If the transmitter's altitude is 4,500ft and the aircraft's altitude is 14,000ft, at what maximum range would the aircraft receive the VOR signals?

$$\begin{aligned} \text{Max Range (nm)} &= 1.25\sqrt{HT} + 1.25\sqrt{HR} \\ &= 1.25\sqrt{4500} + 1.25\sqrt{14000} \\ &= (1.25 \times 67.082) + (1.25 \times 118.322) \\ &= 83.853 + 147.902 \\ &= 231.8\ \text{nm} \end{aligned}$$

6.4.1.3 Protection Range and Altitude

The VOR operates on 40 channels in the 108-112 MHz band (which alternates with ILS frequencies) and a further 120 channels in the 112-117.95 MHz band.

Limited channel space is available and often it is found that different beacons around the country use similar or even the same frequency and it is necessary to protect stations signals from interfering with each other.

This protection is required not only in range between stations but also in altitude, since VOR signals travel in straight lines. When VOR beacons are sited, these factors are considered when determining the distance between stations and the frequency in use.

6.4.2 VOR Rated Coverage

The maximum useable range one is allowed to select and use any navigation aid is known as its rated coverage.

The general rated coverage for all VOR beacons can be found in the AIP GEN section and also in the Jeppesen Radio Aids section, page AU1 par 3.2. An extract from the Jeppesen is included below:

3.2 RATED COVERAGE

3.2.1 VOR and DME

Aircraft Altitude (feet)	Range (NM)
Below 5000	60
5000 to below 10,000	90
10,000 to below 15,000	120
15,000 to below 20,000	150
20,000 and above	180

NOTE: The above ranges are quoted for planning purposes. Actual ranges obtained may sometimes be less than these due to facility and site variations.

VOR beacons may have additional restrictions on range and/or accuracy limitations due to the location of the specific beacon and the nature of the surrounding terrain.

These additional restrictions affecting the rated coverage of a specific VOR can be found in the Jeppesen Radio Aids section, from page AU37 onwards. This is the same table used for NDB rated coverage.

JEPPESEN 27 JAN 17 **RADIO AIDS** **AU-39**

NAVAID LIMITATIONS - AUSTRALIA

LOCATION IDENT	NAVAID	LIMITATIONS
Gayndah, QLD		
GAY	NDB	Range: 60
Georgetown, QLD		
GTN	NDB	Range: 30

LOCATION IDENT	NAVAID	LIMITATIONS
Hobart, TAS		
HB	NDB	Range: 45
HB	VOR	Coverage reduced by terrain shielding in all sectors.

6.4.3 VOR Position Fixing Rules

There are specific rules to apply when using the bearing information from a VOR for position fixing purposes or when fixing the aircraft's position as the aircraft flies overhead the VOR and the indications of station passage are observed.

These rules can be found in the Jeppesen Air Traffic Control section, page AU507 par 5.5:

5.5 POSITION FIXING

5.5.1 A positive fix is one determined by the passage of the aircraft over:

a. a NDB; or

b. a VOR station, TACAN site or marker beacon; or

c. a DME; or

d. is one determined by the intersection of two or more position lines which intersect with angles of not less than 45° and which are obtained from NDBs, VORs, localizers or DMEs in any combination. For the purpose of this paragraph, a position line must be within the rated coverage of the aid with the exception that if a fix is determined entirely by position lines from NDBs, the position lines must be within a range of 30 NM from each of the NDBs; or

e. is one determined by GNSS meeting the equipment and pilot requirements of Area Navigation Systems Approval and Operations.

NOTE: GNSS is not a positive fix for separation purposes.

6.4.4 VOR Information Available on Charts

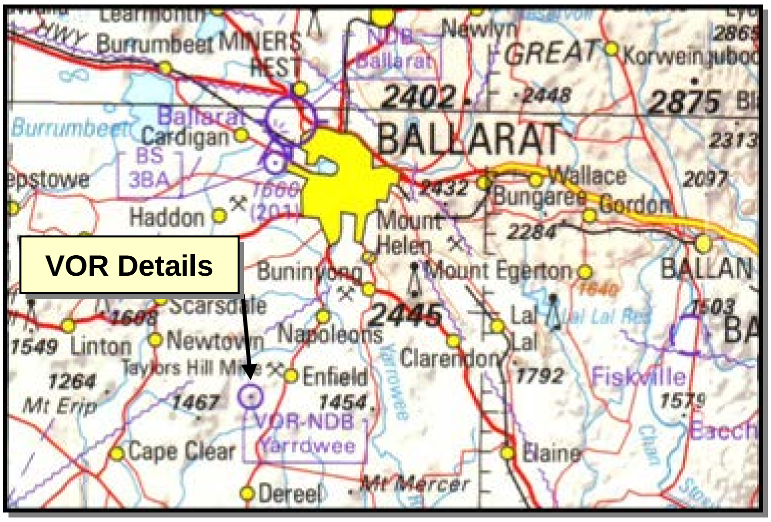
Limited information regarding VORs can be obtained from the various aeronautical maps and charts available in Australia.

The amount of information available varies between the charts, with the WAC having the least information, the VNC and VTC having slightly more information and the en-route radio navigation charts from the Jeppesen or Airservices (ERC) having the most information. Examples of the level of information available on each chart type can be found below:

6.4.4.1 VOR Information on the WAC

Minimal information is shown on the WAC regarding a VOR. In the picture below indicates a VOR located at Yarrowee. The chart does not indicate the frequency or ICAO identifier of the beacon.

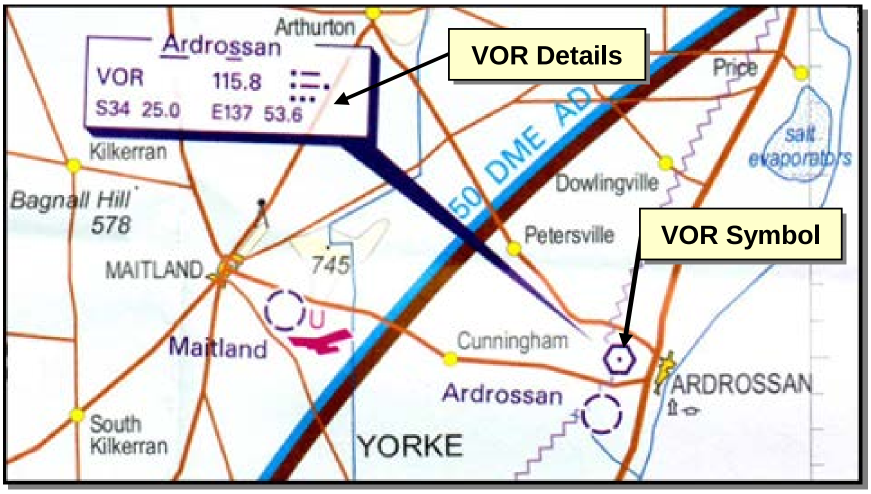
The WAC does not make use of ICAO standard symbols for a VOR and instead uses a single circular symbol for any radio beacon type.



6.4.4.2 VOR Information on the VNC

The VNC makes use of a special symbol for the VOR, which conforms to the ICAO standard set of symbols. A text box next to the beacon depicts the following:

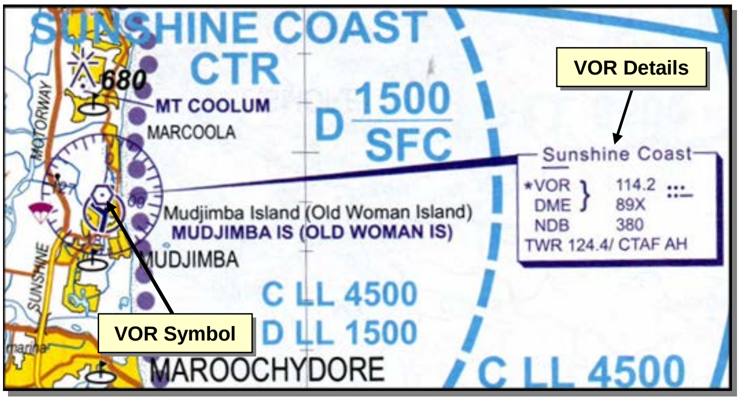
- ICAO Identifier – ARS (underlined letters of **Ar**dro**s**san)
- Frequency – 115.8 MHz
- Morse Code decode for Alpha Romeo Sierra



6.4.4.3 VOR Information on the VTC

The level of information on the VTC is similar to the VNC:

- ICAO Identifier – SU (underlined letters of **Su**nshine Coast)
- Frequency – 114.2 MHz
- Morse Code decode for Sierra Uniform
- The asterisk(*) denotes limited functionality – refer to Jeppesen Radio Aids page AU42.

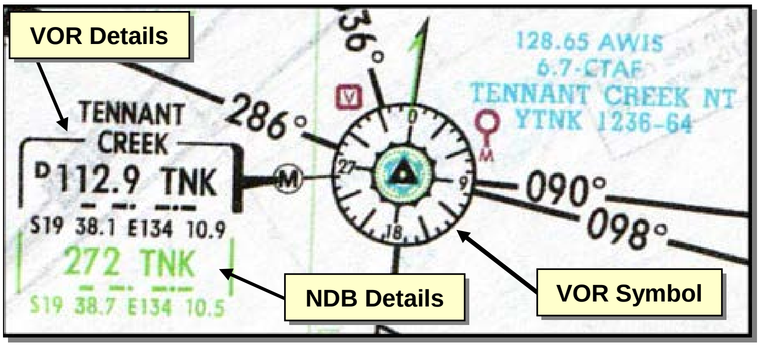


6.4.4.4 VOR Information on the Jeppesen En route Charts

The highest level of beacon related information can be found on the en route charts. The standard ICAO symbol is used for the VOR. A text box next to the beacon depicts the following:

- Plain language name of the VOR – Tennant Creek
- ICAO Identifier – TNK
- Frequency – 112.9 MHz
- Morse Code decode for Tango November Kilo

- Coordinates of the VOR



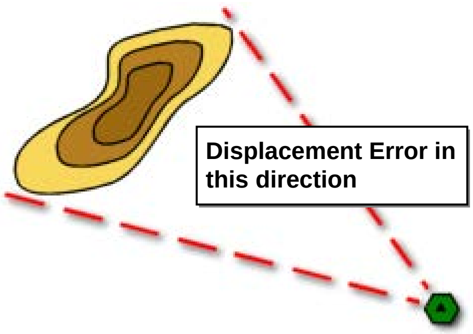
6.4.5 Factors Affecting Accuracy

The following factors affect the transmission accuracy of the VOR:

- Site and Propagation Errors
- Airborne Equipment Error
- Pilot Error
- Interference Error

6.4.5.1 Site and Propagation Errors

- Site Error. Obstacles either man made or natural in the vicinity of the transmitter can cause reflections of the signal resulting in errors: ±1°.
- Propagation Error. Irregular terrain between the transmitter and the aircraft cause further anomalies resulting in oscillations of the VOR needle. Slow oscillations are described as **bends** rapid oscillations as **scalloping** resulting in errors of a maximum of ±2°.



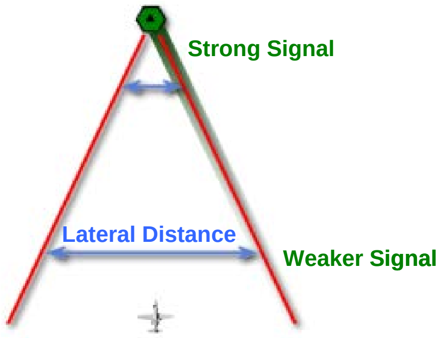
Site and Propagation Errors can be combined and referred to as a **total ground beacon error** of ±3°.

6.4.5.2 Airborne Equipment Error

Airborne equipment error occurs in the process of the receiver measuring the phase difference of the two signals and then accurately displaying them on the navigation equipment. Airborne equipment error is ±3°.

6.4.5.3 Pilot Error

When the aircraft is close to the station the signal strength is strong and the distance between radials is small. This increases the sensitivity of the VOR needle and it will indicate changes in track instantaneously. This adds difficulty in both maintaining tracks as well as reading bearing information accurately.



As the distance from the station increases the opposite is experienced and delay can be expected for the VOR needle to indicate a change in track, reducing the risk of reading the instrument incorrectly.

In planning calculations, this error is given a fixed value of **± 2.5°**.

The combination of site, propagation, airborne equipment and pilot errors is called a **VOR aggregate error**.

These errors are easily calculated by taking the square root of the sum of the squares of the three types of errors.

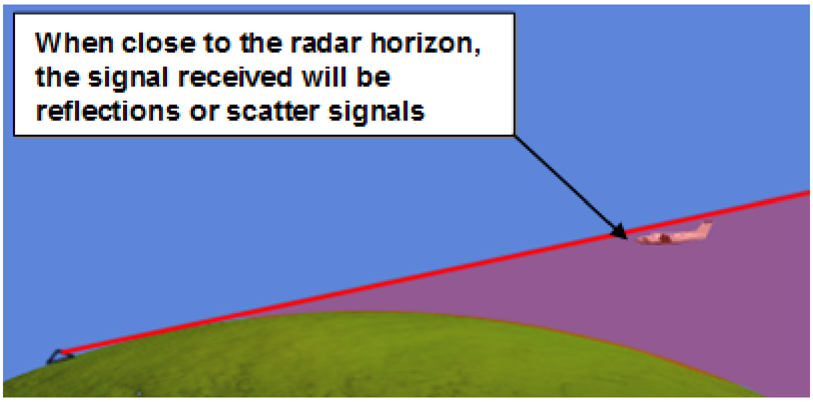
For example, if the error due to site and propagation is 3°, and the error in the airborne equipment is 3°, and pilot error is 2.5° then:

$$\begin{aligned}\text{Aggregate Error} &= \sqrt{(\text{Total Ground Beacon Error})^2 + (\text{Equipment Error})^2 + (\text{Pilot Error})^2} \\ &= \sqrt{(3)^2 + (3)^2 + (2.5)^2} \\ &= \sqrt{24.25} \\ &= 4.92^\circ \\ &\approx 5^\circ\end{aligned}$$

6.4.5.4 <u>Interference Error</u>

Pilots are warned that when using a VOR below the line of sight or outside the rated coverage area can lead to errors in navigation information.

The overall accuracy of the information displayed is ±5° 95% of the time; in the worst case due to other random variable errors this may deteriorate to ± 7.5°.



An avoidable error can be overcome by climbing to a higher altitude or switching to a VOR station that is within line of sight, thus receiving a stronger, direct signal.

6.5 Advantages and Disadvantages of VOR

6.5.1 Advantages of VOR as a Navigation Aid

- In comparison with the previous generation of navaids the VOR provides tracking information in a simpler format.
- Provides tracks through 360°.
- Can be used day or night and is less prone to interference from static.
- VOR ranges can be accurately forecast prior to placing the beacons, thus avoiding signal interference between stations.
- The same airborne equipment (OBS-Omni Bearing Selector or HSI-Horizontal Situation Indicator) can also display ILS (Instrument Landing System) signals.
- It can be frequency-paired with **DME** (Distance Measuring Equipment) to give range information, in addition to the bearing from the VOR.

- By using VHF band the antennas are smaller.

6.5.2 Disadvantages of VOR as a Navigation Aid

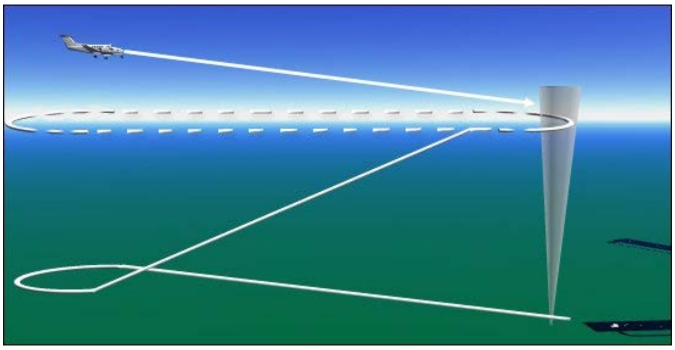
- Unlike the NDB, the VOR does not provide instantaneous orientation in relation to the beacon as its left/right indicator (on the OBI or HSI) does not point to the beacon. Therefore, QDM/QDR information must be taken from a RMI.

- VHF frequencies are limited to line of sight ranges therefore signals can be affected by terrain.
- Requires the use of numerous beacons to provide coverage over a large area, since the VOR has reduced range compared to the NDB.

6.6 Uses of VOR

The VOR may be used in a variety of ways:

- It can provide position lines during en-route navigation to establish position fixes in relation to track.
- As point source navigation aid at destination, useful to home to or to track on a specific track away from the airfield.
- As fixing aid on which holding patterns and instrument approaches are based.



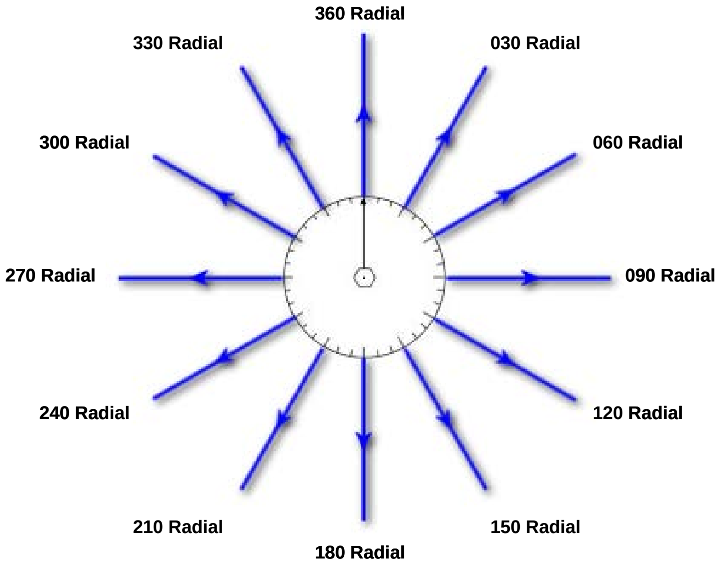
6.7 Use of VOR Bearing Information

The VOR indicator provides the flight crew with positional information in relation to the magnetic bearing selected on the OBS.

The instrument is a command instrument and it indicates whether the aircraft's position is either left of track, right of track or maintaining the selected track.

The method of phase comparison used by the VOR receiver ensures that each bearing can be identified by its own unique signal.

Each individual signal can be thought of a magnetic track or a bearing that radiates out from the ground station.



There are 360 different tracks radiating away from the VOR ground station, each separated by 1°. All tracks are referenced to the VOR station's Magnetic North and they are referred to as radials.

The terms QDM and QDR can also be used when referring to VOR. QDM being the magnetic bearing to the station and QDR the magnetic bearing from the station.

A radial is the magnetic bearing <u>outbound</u> from the VOR.

6.7.1 VOR Radials

VOR radials, as obtained from the various indicator types, are always in degrees magnetic. The magnetic bearing TO the beacon is used for homing purposes and the radial FROM the VOR is used to fix the aircraft's position, verify track or calculate groundspeed (depending on its orientation to the FPT).

Radials FROM the VOR are usually plotted in degrees True when used on a chart for position fixing purposes.

Note that with the VOR the variation at the station's position must be used when converting between true and magnetic. The beacon is calibrated to have zero phase difference between the reference and directional signal at the station's Magnetic North reference.

6.8 VOR Equipment

The VOR airborne equipment consists of the following three main elements:

Indicator - Either OBS, HSI or RMI.

Receiver - The VOR receiver compares the phases of the reference and variable phase signals and feeds the extracted phase difference to the indicator.

Antenna - The antenna consists of small, horizontal dipoles capable of accepting horizontally polarised signals in the frequency band 108.0 MHz to 117.95 MHz.

It will also accept the ILS (Instrument Landing System) localiser signals that operate on frequencies located between 108 and 112 MHz (odd decimals).

6.8.1 VOR Indicator Types

Three types of indicators can be used to display VOR information:

- Omni-Bearing Selector (OBS)
- Horizontal Situation Indicator (HSI)
- Radio Magnetic Indicator (RMI)

The OBS and HSI depict VOR data in a similar manner, the only difference is that the HSI has compass inputs and the OBS does not. These two indicators are best when the pilot wants to maintain a specific magnetic track TO or FROM the beacon and (through manipulation) can be used to find the current bearing to the beacon.

The RMI displays VOR information in a different format to the OBS and HSI. Even though it is still possible to use the RMI to intercept and maintain a specific magnetic track to or from the VOR, it is best suited to finding the aircrafts current magnetic bearing to or from the VOR.

Light aircraft are equipped with an OBS or HSI or both, while multi engine aircraft could have all three indicator types. It is up to the pilot to know which indicator is best to use for the intended task.

A brief overview regarding the layout and functionality of each indicator type is discussed below, followed by a detailed description of the use of an OBS in flight.

6.8.1.1 <u>VOR Indications on the OBS</u>

The VOR indicator (OBS) consists of three components:

- Omni-Bearing Selector (OBS)
- TO / FROM Indicator
- Course Deviation Indicator. (CDI)

Furthermore it has a manually rotatable compass rose which is adjusted by means of the OBS knob. This is used to select the desired VOR radial, which is displayed above the top yellow triangle. **Turn the OBS until the selected radial appears above the yellow triangle.**

6.8.1.2 <u>VOR Indications on the HSI</u>

VOR/ILS indicators can also be incorporated into a **Horizontal Situation Indicator** (HSI).

Horizontal Situation Indicator

This instrument is different to the OBS in that the compass card has flux valve inputs and rotates as heading is changed.

The yellow bar can be manually adjusted to select a specific magnetic track to or from the VOR and functions identical to the OBS.

A course deviation indicator is incorporated into the design of the yellow bar to depict the aircraft's position relative to the selected track.

6.8.1.3 VOR Indications on the RMI

The RMI is a repeater from a remote gyro compass system on which radio bearings may be shown. The sharp (head) end of the pointer is the QDM and the blunt (tail) end is the QDR. QDRs are referred to as radials when VOR bearings are displayed. There are normally two needles, a single needle (**No 1**) and a double needle (**No 2**) of different colours.

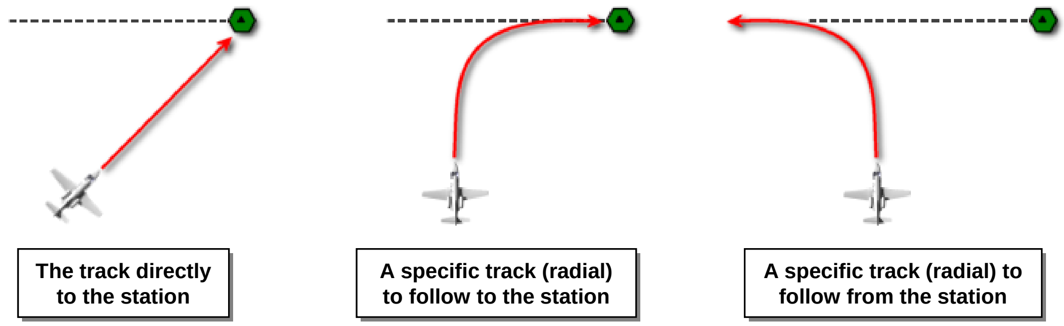
RMI

If the aircraft has two separate VOR receivers, controllers and antennas; then each needle could be selected to a different VOR or to the same VOR beacon if so desired.

Since the RMI can also display NDB bearings, provided the aircraft has the required receiver units, any combination of VOR or NDB bearings could be displayed, making it possible to obtain multiple bearings from different beacons simultaneously.

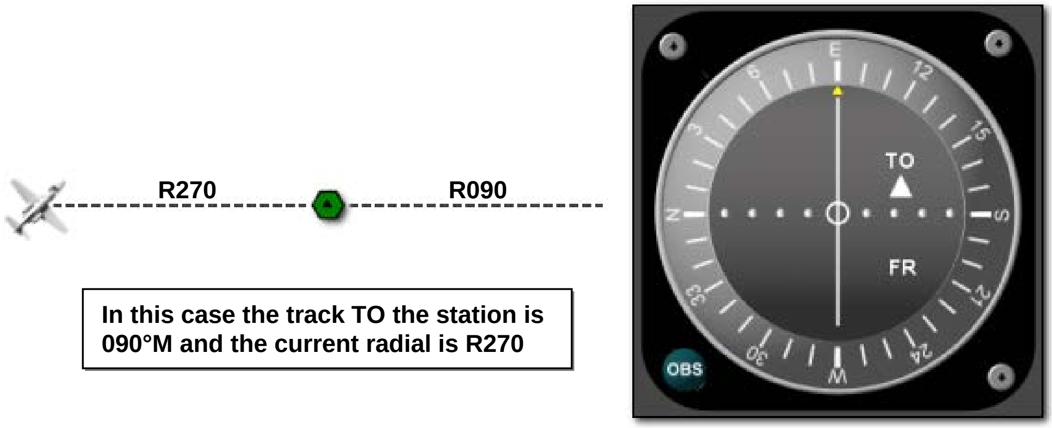
6.9 Omni-Bearing Selector

The OBS control knob is used by the pilot to select the magnetic track he or she wishes to fly either **TO** or **FROM** a VOR station. The following may be selected:



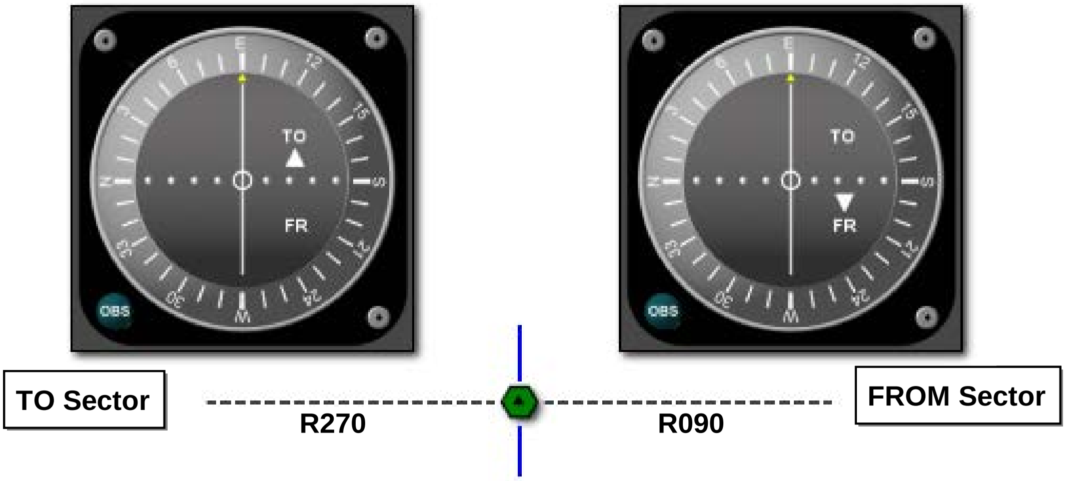
The CDI (Course Deviation Indicator) indications on a conventional OBS show tracking information in relation to the bearing selected with the OBS. The **TO** and **FROM** indications are derived independently of aircraft heading. This will be explained later.

If you wish to track from the aircraft's present position direct to a VOR station. You turn the OBS knob until the course deviation indicator needle is centred and **TO** is indicated in the **TO/FROM** window. The number that is indicated at the top of the compass rose is the magnetic track to fly **TO** the station. The number displayed at the bottom of the compass rose opposite the track is the radial (magnetic bearing from) on which the aircraft is presently located.



The LEFT/RIGHT deviation needles will indicate the amount of degrees left or right from the selected track as it moves in relation to the centre position. If the deviation needle is centralised by using the OBS knob, the aircraft's current radial or its reciprocal will be shown at the pointer.

The selection of track or radial using the OBS knob and the radial on which the aircraft is currently located influences the display of **TO** or **FROM**. In the example below the 090° track has been selected and the aircraft is located on the 270° radial, therefore the **TO** flag will be displayed. This **TO** indication appears regardless of the aircraft's heading. **TO** will change to **FROM** (and vice versa) when the aircraft crosses the **radial located at right angles to the selected track**.



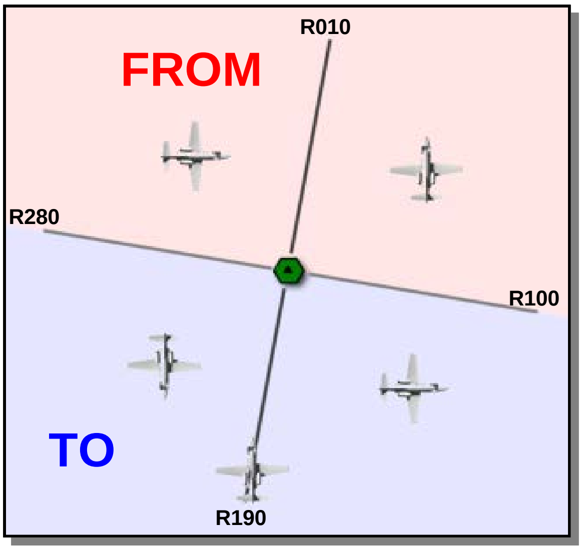
If the selected track is close (within ± 80°) to the radial on which the aircraft is presently located then a FROM flag will appear. If the selected track is different (greater than ±80°) then a TO flag will be displayed.

6.9.1 TO / FROM Indicator

In the following example, five aircraft are situated in different sectors around a VOR station. All have selected track 010 on the OBS, resulting in different **TO/FROM** indications being presented.

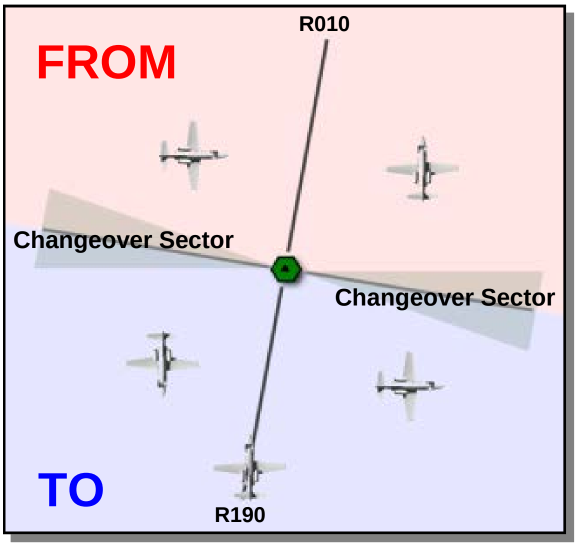
The VOR sectors are divided as follows:

- The FROM sector is situated north of the station. If any bearing (i.e. track) between 281° and 099° is set then the **TO/FROM** window displays a **FROM** indication.



- The TO sector is situated south of the station. If any bearing (i.e. track) between 101° and 279° is selected the **TO/FROM** window displays a **TO** indication.

The **changeover sectors** are 10° either side of a radial 90° from the selected track. This is where the **TO** and **FROM** flags will change (indicating **TO** or **FROM** the specified radial set by the OBS).

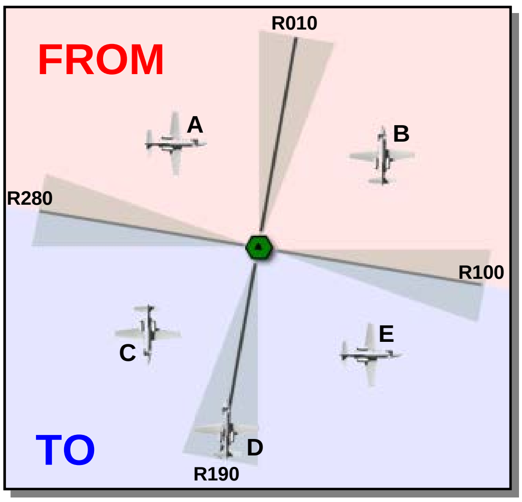


With the 010° track selected by all aircraft, aircraft **A** and **B** will indicate **FROM** in the **TO/FROM** window as they are situated in the **FROM** sector, since in this case track 010°M leads away **FROM** the VOR.

Aircraft **A** will have a fly right indication on the CDI as the selected track of 010° is to the right of the aircraft. Aircraft **B** will have a fly left indication.

Aircraft **C**, **D** and **E** will indicate **TO** in the window as they are situated in the **TO** sector, since track 010°M is (in terms of their positions) a track leading **TO** the VOR.

The deviation needles of aircraft **C** and **E** will not be centred, as they are not positioned on the 190° radial. Aircraft **D** is positioned on the 190° radial, with the deviation needle centred with a **TO** indication being displayed.



6.9.2 Left/Right Deviation Indicator

The deviation needle moves across a 5 dot horizontal scale to show angular deviation from the selected radial or its reciprocal. Some 5-dot indicators show a centre circle and 4 dots. The edge of the centre circle represents the first dot, making a total of 5 dots.

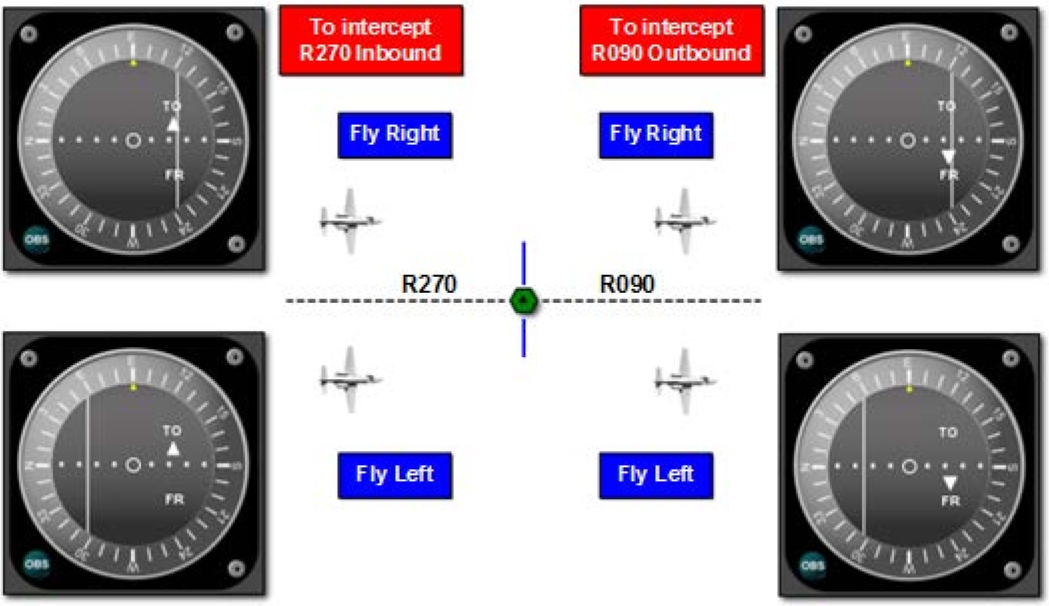
A full-scale deflection equals 10 degrees or more from the selected radial.

Different designs are available, which differ in the amount of dots on the indicator. The following representations are used:

- 5 Dot-indicator: Each dot equals 2° from the selected radial
- 4 Dot-indicator: Each dot equals 2.5° (In this design there is no centre circle)
- 2 Dot-indicator: Each dot equals 5°

The **Course Deviation Indicator (CDI)** is a command instrument, the centre dot or circle is the aircraft, and the Left/Right deviation of the needle is the command. Remember that the **To/From** indications are generated independently of heading, therefore the aircraft may be flying a heading that is in opposition to the commands given by the CDI.

If the aircraft heading and OBS setting are more than 90° apart, then Left/Right commands are not valid, i.e. the needle sense is reversed. The CDI is not in “Command Sense”.



If the aircraft heading and OBS setting are similar then

LEFT/RIGHT commands are valid.

If homing to a station (inbound), the main concern is the state of the **TO/FROM** window. Centre the deviation needle and take note of the **To/From** window. With the window indicating **TO**, steer a heading to make good the magnetic track indicated by the OBS, by allowing for any drift.

To maintain a radial outbound, select the radial with the OBS, with **FROM** indicated. Fly a heading to make good the magnetic track away from the VOR as indicated by the OBS, by allowing for any drift that might be affecting the aircraft.

6.9.3 Operational OBS Use

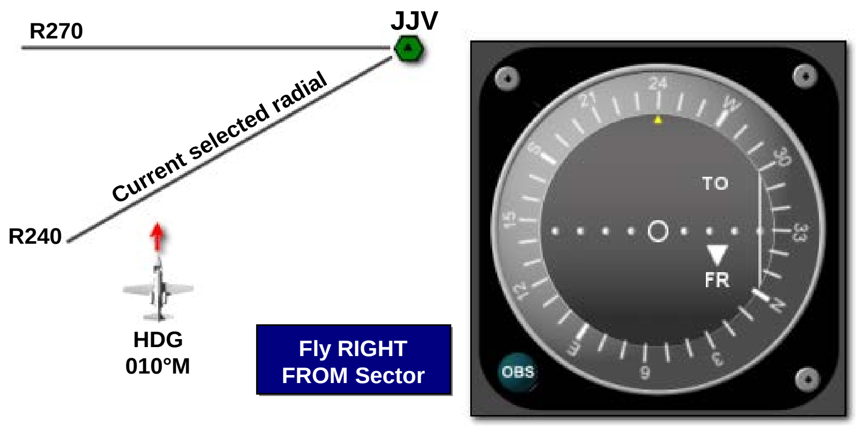
Consider a pilot on a navigation exercise, heading 010°M and the VOR tuned to the JJV VOR with the 240° radial selected.

The following will illustrate the different VOR indications presented by the instrument as the aircraft approaches, crosses and passes the 240° radial. Thereafter, the procedure to follow and intercept the 270° radial JJV inbound will be explained and **the pilot is not required to intercept radial inbound**.

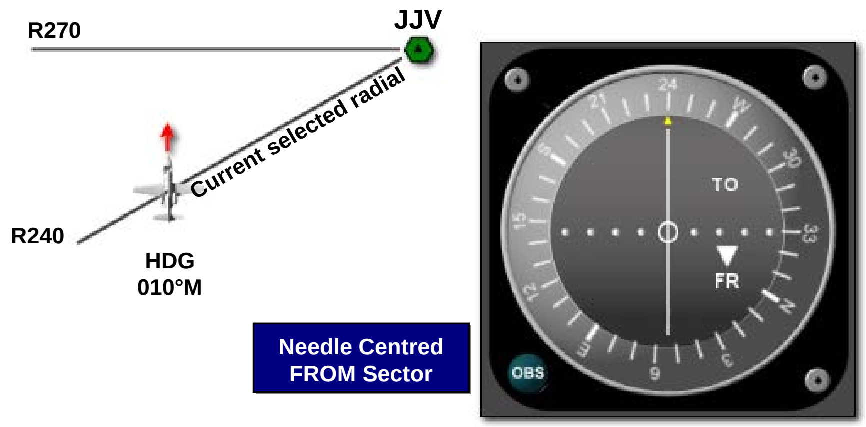
The VOR indicator is set on the 240° radial JJV, with the deviation needle deflected right (**FROM** Sector), which indicates that the aircraft must fly right to intercept the 240° radial (this is regardless of the aircraft's heading).

Note that the **FROM** (FR) flag is shown due to the current selected track of 240°M leads away **FROM** the VOR, while the current heading is towards the VOR.

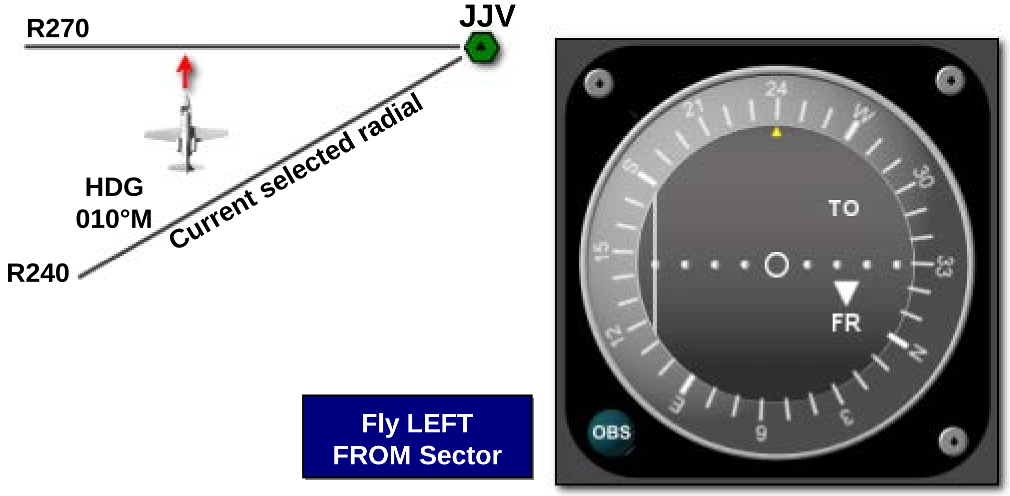
In the top down view below, the selected track (R240) is actually on the aircraft's left, yet the OBS display is indicating a "fly right" command.



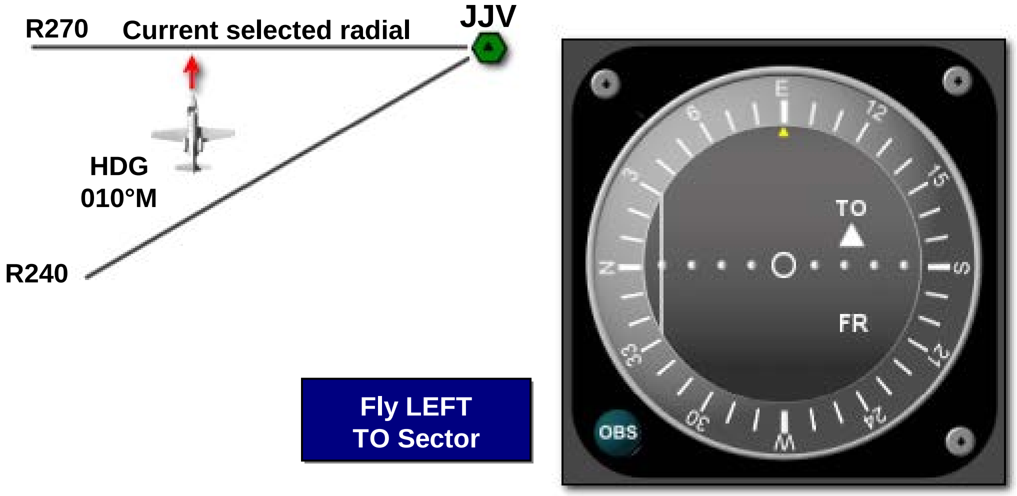
Maintaining a heading 010°M the needle will pass from right to left and pass the centre circle as we cross over the 240° radial JJV.



In this example the OBS radial selection and the aircraft heading is different (within a 180° half circle: 150° to ° to 330°) therefore the CDI is revered (i.e. not in command sense, normal used to determine the aircraft's position relative to the VOR and is <u>not</u> associated with the procedure to intercept the inbound radial).



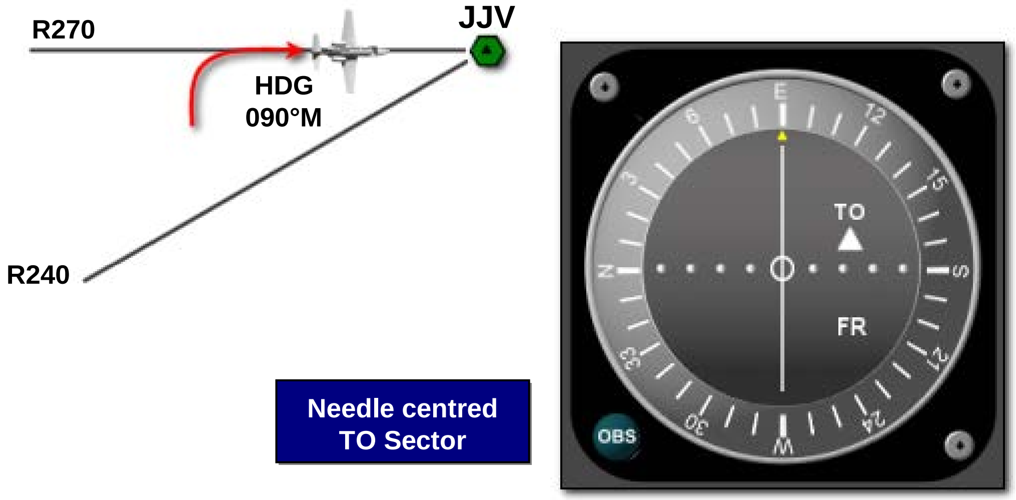
As the aircraft crosses the 240° radial JJV, the ATC instructs the pilot to intercept the 270° radial inbound towards JJV (flying inbound on a heading of 090°M). As the VOR indicator is set to the 240° radial the 090° (reciprocal of R270) radial has to be selected with the OBS knob.



With the OBS set to the track of 090° **TO** (270° radial inbound) the pilot maintains the present heading of 010°M (90° intercept angle) until the CDI starts moving from left to right, indicating that the aircraft is within 10° from the selected radial.

With the OBS set to the reciprocal the **TO** flag is displayed and the selected track of 090°M will lead **TO** the VOR. The indicator is operating in command sense and indications can be interpreted as the action the pilot must take to intercept the selected magnetic track.

Once the needle starts to move the aircraft turns right, onto a heading of 090°M, to intercept the 270° radial inbound. The aircraft needs to make good a track of 090°M in order to remain on R270 JJV inbound, which might require minor adjustments to heading due to changes in drift and changes to the aircraft's position relative to the selected track.



The example above was an illustration of just one possible way in which the OBS can be used for positioning the aircraft relative to a VOR in order to track a specific radial inbound. A similar procedure can be used to track a radial outbound from the VOR.

6.9.3.1 Summary of OBS Operational Use

In the operation of the OBS the following key concepts must be taken note of:

- Follow the procedure to select (tune) the desired VOR frequency, as described later in this chapter.
- The desired VOR magnetic track is manually selected by turning the OBS knob.
- The CDI needle indicates the degrees offset from the selected track / radial by means of the dot scale.
- Maximum scale deflection is always 10° and not all indicators have the same amount of dots. Interpret the dot scale to assess how far the aircraft is away from the radial.
- The TO/FROM flags indicate in which sector the aircraft is.
- To home to a VOR station the CDI must be centred and the TO flag must be displayed and then maintain the track indicated above the OBS bug.
- Tracks or radials indicated by the instrument are magnetic as the VOR station is calibrated (aligned) to magnetic north.

6.10 Procedure to Select the VOR

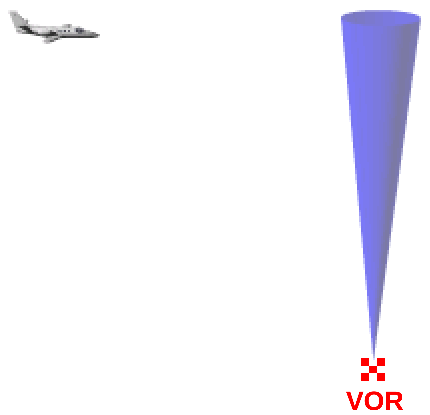
The procedure below is a generic operating procedure for using the VOR system. Refer to the aircraft manual for more specific instructions as variations in style or design of cockpit controllers exist.

- Consulting the AIP or Jeppesen for the designated operational coverage of VOR stations.
- Switch on the equipment and test. (This step is usually done while still on the ground, before taxi.)
- Select the desired VOR frequency.
- Check that the warning flag (an OFF or NAV) on the HSI and RMI disappears.
- Identify the station by listening to the Morse code identification.

VOR's transmit a 3-letter aural Morse group at least once every 10 seconds. The voice channel may also be used to pass on weather or aerodrome information.

- As mentioned earlier the VOR instrument can also be tested by tuning to the VOT (Test VOR beacon) at the airfield.

6.11 Cone of Confusion



A cone shaped volume of space exists above the VOR transmitter in which signals will not be received.

Called the **Cone of Confusion** or **Cone of Silence** due to the temporarily loss of signal of the VOR station.

The ICAO propagation specifications require the signals to be transmitted up to 40° in elevation. Modern equipment transmit signals up to 80° above the horizon.

Operationally this cone is used to identify when the aircraft is directly above the station for position fixing purposes.

Note: The time spent in the cone depends on height and ground speed.

6.12 Indications of Station Passage

When using the **OBS** to home to the VOR, the indications of station passage are as follows:

- On the OBS, the CDI needle moves from the centre towards one of the sides, as the aircraft enters the cone of silence.
- OFF or NAV warning flags may appear temporarily. Many VOR receivers have delay circuits to prevent this event.
- Swapping between TO/FROM indications prior to changing to FROM.

When using the **RMI** to home to the VOR the RMI needle fluctuates then rotates through 180°. There is 180° difference between the RMI bearing indications before and after passing over the beacon.

6.13 Worksheet – VHF Omni-Directional Range

1. Which frequency band(s) does VOR operate in?
   a. VHF band only
   b. LF and MF bands
   c. HF and VHF bands
   d. VHF and UHF bands.

2. The principle of operation of the VOR can be described as:
   a. Radar ranging
   b. Phase comparison
   c. Loop theory
   d. Timing of signals.

3. The shape of the polar diagram of the VOR can be described as:
   a. A cardioid
   b. Omni-directional
   c. A limacon
   d. Directional and rotated at 30 Hz.

4. Which statement is true regarding the principle of operation of a VOR?
   a. The time it takes the signal to travel to the aircraft is converted into range.
   b. The null position is used for direction reference.
   c. The reference signal is rotated 30 times a second.
   d. The phase difference between signals relates directly to bearing from the VOR.

5. What is VOR aggregate error?
   a. The bearing error caused irregular terrain between the VOR and the aircraft.
   b. The error caused by refraction the further inland a coastal VOR is located.
   c. The square root of the sum of the squares of site, propagation, airborne equipment and pilot errors.
   d. The error resulting from using a VOR outside the rated coverage area.

6. Which of the following is not an error affecting the VOR?
   a. Site error

b. Night effect

c. Interference error

d. Aggregate error.

7. An aircraft is flying at 4,500ft AMSL. What is the rated coverage for the VOR located at Tailem Bend airport?

   a. 60 nm

   b. 65 nm by day or night

   c. 65 nm by day only

   d. 90 nm.

8. An aircraft is flying at 6,500ft AMSL. What is the rated coverage for the VOR located at Canberra airport and are there any further restrictions to this beacon's range?

   a. The rated coverage is limited to only 30nm, due to terrain.

   b. The rated coverage is limited to 60nm and scalloping can be expected around R159.

   c. The rated coverage is 90nm and there are no other restrictions.

   d. 60nm by day.

9. An aircraft is maintaining R225 inbound to a VOR. Which statement below is correct?

   a. To stay on the radial the aircraft must steer heading 045°M.

   b. To stay on the radial the aircraft must steer heading 225°M.

   c. To stay on the radial the aircraft must track 045°M.

   d. To stay on the radial the aircraft must track 225°M.

6.13.1 Worksheet Answers

1A	2B	3C	4D	
5C	6B	7A	8C	9C