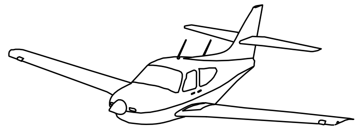


3.1.4 Radio aids to navigation

3.1.4.1 Non-directional beacons (NDB's) and the Automatic Direction Finder (ADF)

These beacons operate in the low (LF) to medium (MF) frequency range, between 190 - 415 kHz and between 510 - 535 kHz.

Signals from these beacons follow the curvature of the earth. They are thus not restricted to line of site operation

Because of their design and the frequency range in which they operate, they are subject to many errors which include:

- **Night effect** - greatest just before sunrise and just after sunset. The effect can be minimised by selecting lower frequencies (those below 350kHz are subject to very little error), flying higher, using beacons close by (within 20 - 40 nm) or averaging the effect on the needle.
- **Mountain effect** - the effect can be minimised by not using stations obstructed by mountains.
- **Quadrantal/banking error** which is a significant source of error when flying approaches.
- **Coastal effect** - greatest when within 30° of the coast line. The effect can be minimised by using beacons located right on the shoreline such as marine beacons or beacons where the line from the beacon to the aircraft is larger than 30°.
- **Electrical storms**.
- **Icing and sleet** can cause erroneous readings.
- **Precipitation static** - this effect can be reduced by slowing the aircraft down

Approximate time and distance to a NDB

When passing abeam of a NDB, it is possible to estimate your time and distance to the station through the use of the following approximations:

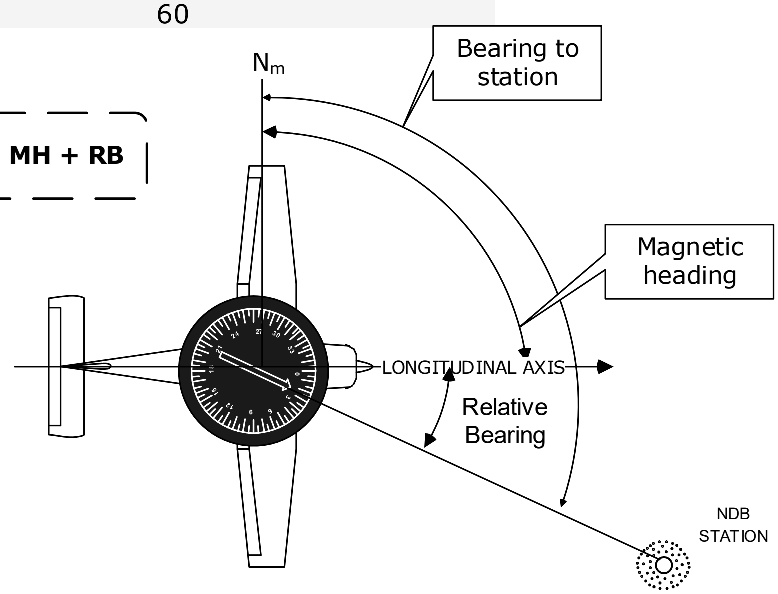
$$\text{Time to NDB (minutes)} = \frac{\text{time(secs)}}{\text{degrees of relative bearing change}}$$

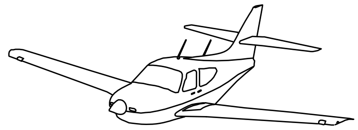
$$\text{Distance to NDB (nm)} = \frac{\text{Groundspeed (knots)} \times \text{Time to NDB (minutes)}}{60}$$

Bearing to an NDB

To determine the bearing to the station, you need two pieces of information – the magnetic heading (MH) and the relative bearing (RB) as shown. The bearing to the station will be equal to the magnetic track to the station and the magnetic heading to the station in zero wind conditions

BTS = MH + RB





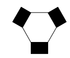
3.1.4.2 The VOR (VHF Omni-directional Radio Range)

The VOR operates in the very high frequency (VHF) range of 108.1 (112.1) - 117.95MHz.

VOR is restricted to line of sight navigation

Not subject to as many errors/interference as the NDB

 VOR

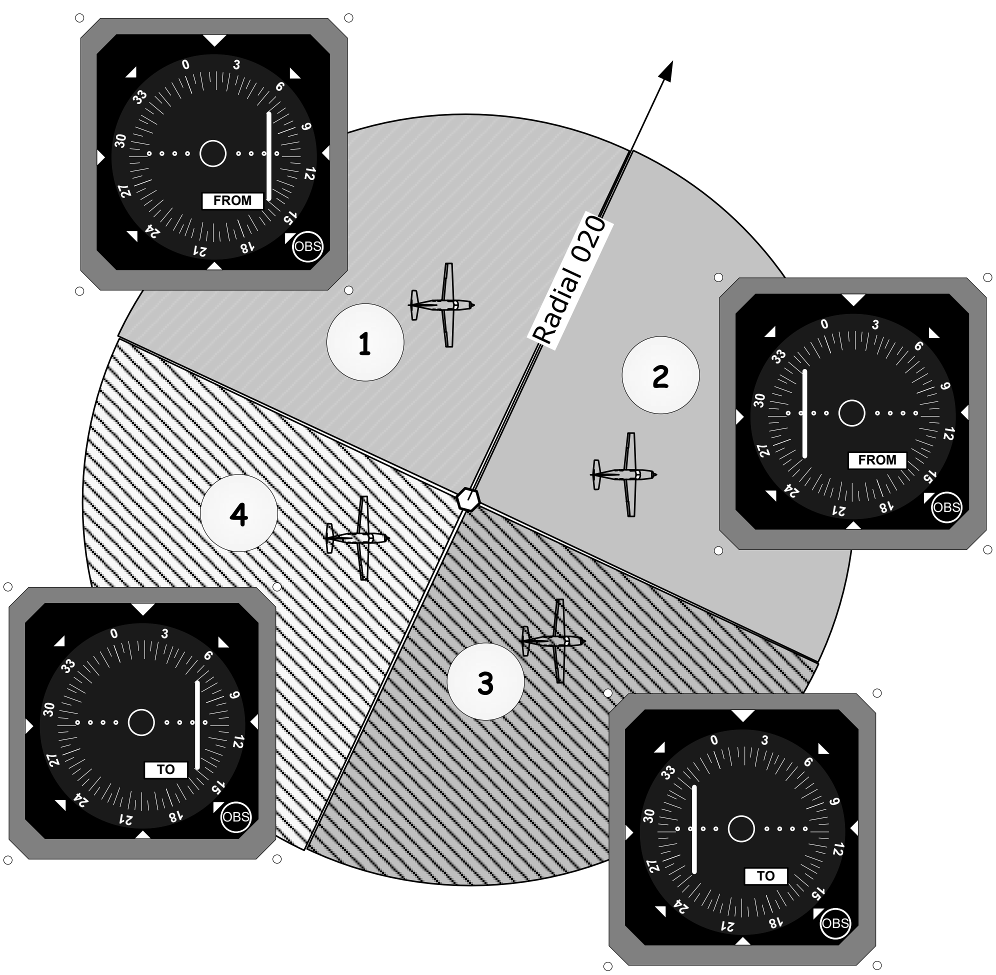
 VORTAC

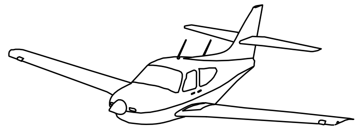
The course deviation needle has the function of indicating deviation from the selected radial. It has a maximum range of ± 10º from the selected radial.

The TO/FROM indicator indicates which side of the VOR station the aircraft is on relative to the selected radial. If the aircraft is on the same side (within ±90° - ie in segments 1&2) of the station as the selected radial then the TO/FROM indicator will show FROM while if it is on the reciprocal side to the selected radial (outside of ±90° - ie in segments 3&4) then it will indicate TO.

The deflection of the needle is not dependent on the aircraft heading !

The VOR needle will indicate the correct direction (but not the actual heading) to turn to intercept the selected radial from your present position provided your heading is approximately parallel to the radial selected with the OBS



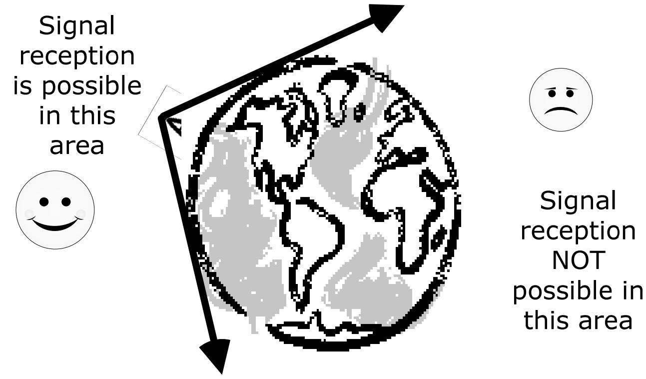


Useful formulae for the VOR

Range limitations of the VOR

The range limitations (line of sight) of the VOR are illustrated through the application of a formula which enables one to calculate the maximum range of a VHF facility.

$$\text{Range (nm)} = 1.25 \times \sqrt{\text{altitude (feet)}}$$



Approximate time and distance to a VOR station

When passing abeam of a VOR station, it is possible to estimate your time and distance to the station through the use of the following approximations:

$$\text{Time to VOR (minutes)} = \frac{\text{time (secs)}}{\text{number of radials crossed}}$$

$$\text{Distance to VOR (nm)} = \frac{\text{Ground speed (knots) x Time to VOR (minutes)}}{60}$$

NOTE: In exam problems, you frequently do not know the wind direction or speed. In these problems, you can approximate the ground speed with the true airspeed.

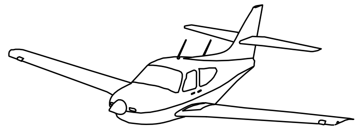
Solved example using the time and distance to VOR formulae

To help illustrate how to use the formulae above, consider the following scenario:

You are flying along and are navigating primarily by pilotage and dead reckoning, but you would like to check your position against some radio navigation aids You know that there is a VOR station off your left wing. From your last ground speed check you know that your ground speed is 120 knots.

After tuning and identifying the VOR you set the OBS so that the CDI centers with the flag indicating "TO". You note the bearing shown on the OBS and the time. To make the mental calculations easier, you decide to check the time after the bearing to the VOR changes by 10°, i.e. after you have crossed 10 radials.

Refer to the following page for details on how to calculate your distance from the VOR...



You note that it takes 200 seconds for the bearing to the VOR station to change 10°. Plugging the numbers into the formulae you get the following result (remember your ground speed is 120 knots);

$$\text{Time to VOR (minutes)} = \frac{200 \text{ seconds}}{10 \text{ radials}} = 20 \text{ minutes}$$

$$\text{Distance to VOR (nm)} = \frac{120 \text{ knots x } 20 \text{ minutes}}{60} = 40 \text{ nm}$$

So now you know that you are 40 nm away from the VOR station.

The heading selected on the OBS with the CDI needle centered is your bearing to the VOR station. The reciprocal of the OBS course (i.e. the course shown on the bottom of the VOR) is the bearing from the VOR to your aircraft, so you draw that onto your chart, and mark 40 nm along that line. The mark you just made is the position of your aircraft.

VOR accuracy:

The VOR is not subject to the errors which plague the NDB and this is part of the reason for its popularity. The accuracy of the VOR is as listed in the table below.

Accuracy: published radials	± 3°
Accuracy: non published radials	None guaranteed although significant deviations on any radial will be indicated in the CFS

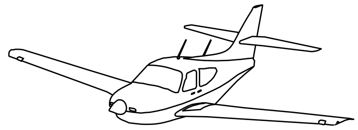
VOR accuracy testing

	REQUIRED ACCURACY
If the system does not meet these requirements then it may not be used for IFR navigation and it probably should not be used for VFR navigation either!	• 2 VOR comparison - ± 4° • Airborne geographic location check - ± 6° • VOR checkpoint – VOR should indicate within ± 4° of the posted radial while the DME should indicate within 0.5nm of the posted distance.

NOTE:

If your equipment seems to pick up the VOR and the indications seem normal but you cannot hear an identifier signal there is a problem!

VOR stations have a self monitoring system. If the monitoring system detects that the station has gone out of calibration then it will remove the identification signal from the station's transmission providing an indication to pilots that the station is faulty.

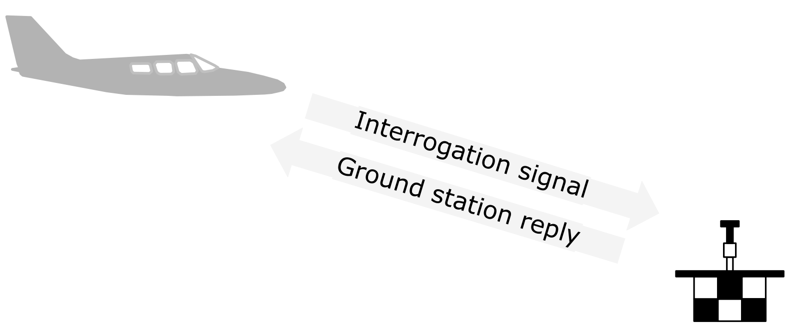


3.1.4.3 Distance measuring equipment (DME)

How it works

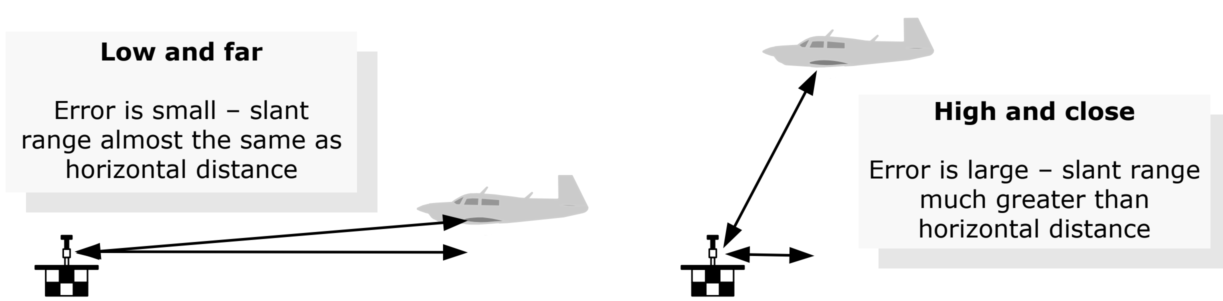
DME operates in the UHF frequency band (300MHz to 3000 MHz), the actual frequency range is 960 to 1215 MHz. DME uses a principle known as secondary radar - the airborne equipment transmits an interrogation signal to the ground station. After a short delay, the ground station responds. The airborne equipment measures the time for the signal to travel from the aeroplane and for the reply signal from the ground station to return. Given that the signal travels at the speed of light, the time for the round trip is then used by the airborne equipment to calculate the distance from the station. Notice that DME measures slant range and not horizontal distance to station as shown in the diagrams below. There is a difference between the slant range and horizontal distance to the station which is greatest when high and close to the station. It is least when low and far from the station.

Like the VOR, DME is limited by "line of sight" - the same formula as for the VOR may be used to determine the maximum range of DME



The principle interrogation and response is known as secondary radar. This is similar to the transponder except that the interrogation signal comes from the airborne equipment while the response comes from the DME station

DME distance readout is slant range not surface distance



Accuracy as measured at a VOR checkpoint should be within 0.5 nm or 3% whichever is the greater