CHAPTER 5
VOR : VHF OMNI RANGE

Introduction

5.1 In the previous Chapter we learnt about Non Directional Beacon as a Navigational aid. We also learnt of the disadvantages of the aid. To improve the reliability factor, the VOR Very High Frequency Omni Range was developed and was adopted as a standard Navigational Aid by ICAO in the early 60s.. Till date, the VOR continues to be the most widely used and most reliable navigational aid in the world.

5.2 The VOR operates in the range 108 to 117.95 MHz. It is practically free from static and more importantly not affected by sky waves making it the most reliable aid for use by day and night. When the DME (Distance Measuring Equipment which gives accurate distance measurement indications, the principles of which we shall learn in a later chapter) is co located with the VOR, it gives a very accurate and instantaneous bearing and range fix.

Principle of Operation

5.3 The VOR operates on bearing by phase comparison principle. The carrier wave is modulated with two signals. They are:-

5.3.1 **Reference Signal.** A 30 Hz frequency modulated omni directional reference signal. This means that the phase produced is constant on all directions from the beacon.

5.3.2 **Variable Signal.** A 30 Hz amplitude modulated variable signal which is generated by electronically rotated so as to produce a pattern which exactly coincides with the reference signal at the magnetic North position line, and the a phase difference is introduced when compared to the reference signal as the direction varies. The phase difference between the reference signal and the variable signal will be exactly equal to the bearing of the aircraft from the station.

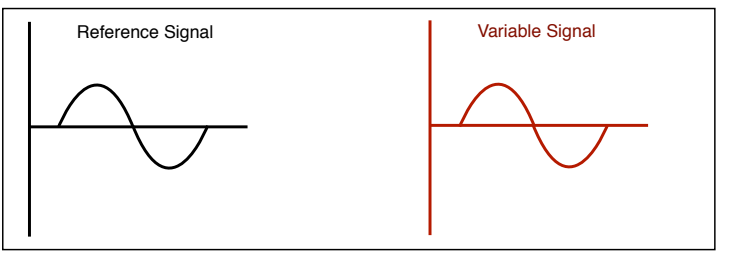
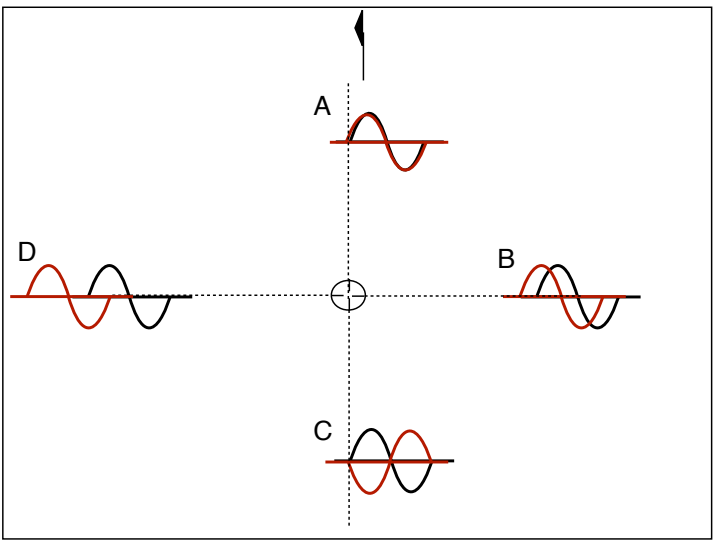


Figure 5.1

5.4 In the figure 5.1 and 5.2 , the two signals transmission patters have been depicted.



5.5 As shown in the figure :-

5.5.1 At position A, which is along the magnetic northerly track from the VOR ground station, the phase difference between the reference and the variable signal is 0 deg. At position D which is on a westerly track, the phase difference is 270 deg.

5.5.2 Similarly, along different position lines the phase difference between both the signals is exactly same as the magnetic track of position.

5.6 The VOR transmission is continuous and the phase difference is measurable at any instant even when the identity signal is transmitted. Thus the aid produces position line or tracks **from** the station. These are called **Radials**.

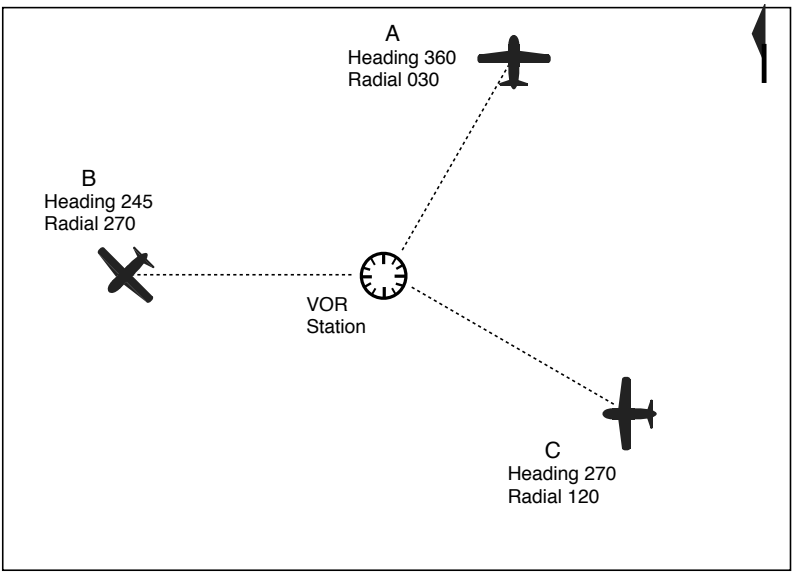


Figure 5.3

5.7 Refer to the Figure 3. The VOR station is depicted at the centre and three aircrafts positions are shown. Aircraft A is on a heading of 360 and its radial from the OR is 030. Similarly, aircraft B and C are on radials 270 and 120 respectively. Notice that the heading of the

aircraft has not relation to the position and hence the radial of aircraft.

Airborne Equipment

5.8 Although there are various types of indicators, they present the same information and are operated in similar manners. In modern cockpits, the entire information is processed and displayed through integrated systems. we shall now discuss the components of a traditional airborne equipment and we shall touch upon indications in modern cockpits. The components of the VOR indicator are: -

5.8.1 **Omni Bearing Selector** (OBS). Also called course selector.

5.8.2 **Course Deviation Indicator** (CDI) the VOR needle, centered when on the selected course and deflected left or right when off track.

5.8.3 **To/From flag**. Indicates whether the selected course would take the aircraft toward or away from the VOR

5.8.4 **On/Off indicator or flag**. Indicates the integrity of the signal quality.

5.8.5 **Radio Magnetic Indicator(RMI).** Pointer imposed on a compass card.

5.8.6. **Frequency Selector.**

5.9 **Omni Bearing Selector** The reference radial that is set on a window. Any deviation indications is based on this radial set.

5.10 **Course Deviation Indicator** The CDI indicates an off course situation by showing the deviation as an angular deviation from the selected course. The reference is the course selected by the OBS and shown at the top of the gauge. The deviation is referred to in terms of "dots" off course. There are five dots to either side of center and each dot represents 2° of deviation. If the aircraft is on the selected radial, the CDI is centered. If the aircraft is 4° off course, the CDI will be deflected two dots from the center (also called the donut). If the aircraft is 10° or MORE off course, a full scale deflection will be shown (five dots).

5.11 Since the off course indication is angular, the closer to the station, the less the actual distance off course. The lateral deviation (distance off course) can be calculated or estimated using the following distances from the station:

- at 1 nm, 1 dot = 200 ft.
- at 30 nm, 1 dot = 30 x 200 = 6000 ft = 1 nm
- at 60 nm, 1 dot = 60 x 200 = 12000 ft = 2 nm

This matches with the 1-in-60 rule which states: 1 nm off course in 60 nm = 1° course error.

5.12 **To/ From** Each radial has a reciprocal radial. In other words, the 090 radial, a bearing of 090 From the station, is the same line as the 270 To the station. If the aircraft is on this line, the CDI will be centered when 090 or the 270 is selected with the OBS. The To/From indicator shows where you are in relation to the station.

5.13 The presentation of the CDI differs depending on the instrument. It may pivot on the top of the needle, the entire needle may move left or right, or in the case of some HSIs, the center portion of the needle will move left or right.

5.14 The other airborne equipment include the antenna which is fixed to the fuselage and the receiver unit which is located in the avionics compartment.

Interpretation

5.15 **RMI.** When the correct frequency is tuned and the signal strength is adequately strong, the head of the needle which gives the VOR indications points towards the beacon. Thus the tail of the needle indicates the radial on which the aircraft is positioned.

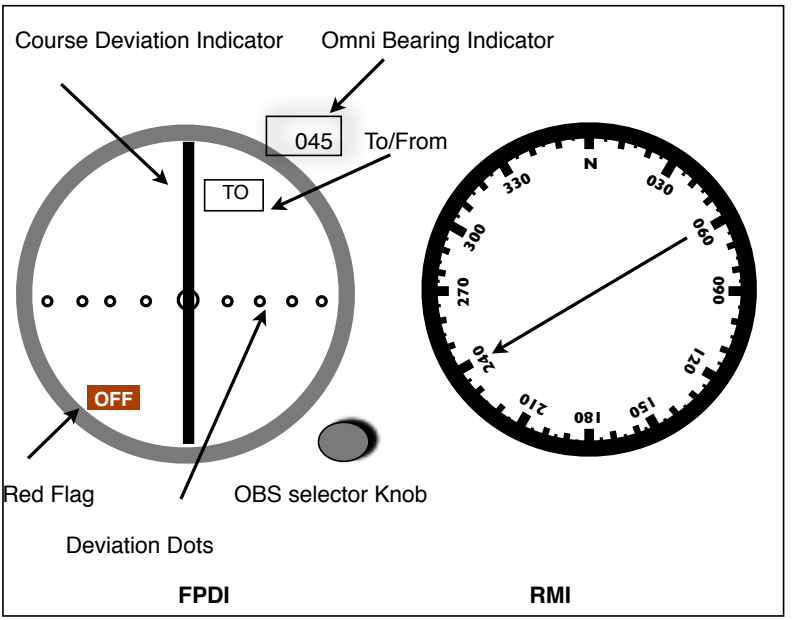


Figure 5.5

5.16 Refer to figure 5.5. The aircraft at position A is on a heading of 360 º and the RMI needle head is indicating a QDM of 210 and the tail is indicating the radial of 030 º. Similarly the aircraft B is on a radial on 210 º.

5.17 **To/From Indicator**. The To/From indicator is and the FPDI (flight Path deviation indicator) indicate in conjunction. This means that the FPDI indications will be different for different OBS selections depending on the position of the aircraft. If the position of the aircraft within

+/- 90 º sector of the radial as selected on the OBS, then the indication is **From** and depending on the position the FPDI will be deflected left or right. If it is not within this sector then the indication will be **To**.

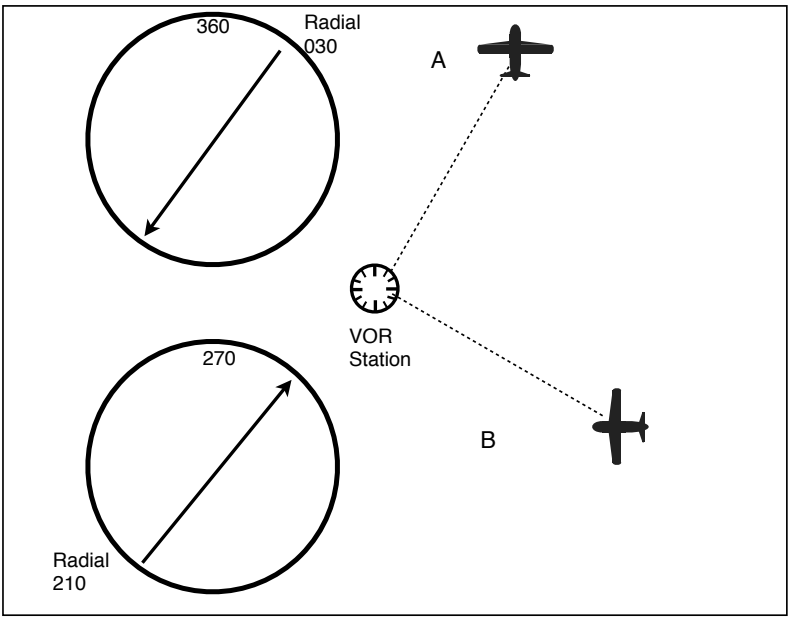


Figure 5.6

5.18 In the figure 6 the aircraft at position B is on a heading of 360, with a fly left indiction on the FPDI and From indication with the OBS selected 045. You may interpret the indication for aircraft at other positions.

Ground Equipment

5.19 **Transmission.** The VOR operates in the frequency range 108.0 MHz to 117.95 MHz.

5.19.1 **108-112 MHz** Even though this range is primarily allocated for ILS, ICAO has permitted for this band to be used for low powered terminal VORs. A total of 40 channels are used. All frequencies with even numeral after the decimal is used for VOR and with an odd numeral for ILS.

5.19. **112-117.95** A total of 120 channels are usable.

5.20 **Emission Code.** The emission code is A9W.

5.21 **Identification.** The VOR station transmits a aural 3 letter Morse code. Some VORs may use voice identification as well.

5.23 **Monitoring.** All VOR stations are monitored at the site of transmissions and indicate failure is case of:-

5.23.1 Bearing information error > 1 deg.

5.23.2 A reduction of > 15 % in strength of any of the signals.

5.23.3 Failure of the monitor itself.

In such cases the bearing signals or the identifier signals are cut off which indicates a red flag in the cockpit or aural code not being heard.

5.24 **Types of VOR.** The following types of VORs are in use:-

5.24.1 **BVOR.** Broadcast VOR used for transmitting weather and ATIS.

5.24.2 **TVOR.** Low powered terminal VORs used for identifying holding positions.

5.24.3 **VOT.** Test VORs. A check of the aircraft indication accuracy can be done. It transmits a constant radial of 180 in all directions. When tuned the FPDI needle is centered with From indication if OBS is tuned to 180.

5.24.4 **DVOR.** Doppler VORs which are installed to reduce site errors.(We shall learn about errors in VOR, later)

5.25 **Designated Coverage.** In order to ensure that no two VORs are located closely so that they do not interfere with each other, they are planned to be separated by approximately by 500 nm by the regulatory authorities.

Factors affecting accuracy of VOR

5.26. **Range.** The following factors affect the operational range of VOR:-

5.26.1 **Transmission Power.** Higher the power the better is the range obtained. Route VOR transmitting at 200 W gives approximately 200 nms range. Low power VORs have much lesser ranges.

5.26.2 **Height of VOR Station and the Aircraft.** The reception is governed by the line of sight and can be derived by the formula

1.25 x (√ Ht of transmitter in 000s + √ Ht of receiver in 000s)

5.26.3 **Terrain.** Nature of terrain such as high structures etc mask the transmission giving lesser ranges.

5.27 **Bearing.** The following factors affect the accuracy of bearing indications:-

5.27.1 **Site Errors.** High hills, Man made structures and even long grass in the transmitter area can affect the bearing information and is monitored within $\pm$ 1 ^{o} .

5.27.2 **Propagation Errors.** Caused by the fact that the VOR signals are further affected b terrain and distance. A considerable ranges, scalloping can occur. Scalloping is defined as an imperfection or deviation in the received VOR signal. It causes radials to deviate from their standard track. It may be indicated as fluctuation in the FPDI needle, sometimes rapidly shifting side to side.

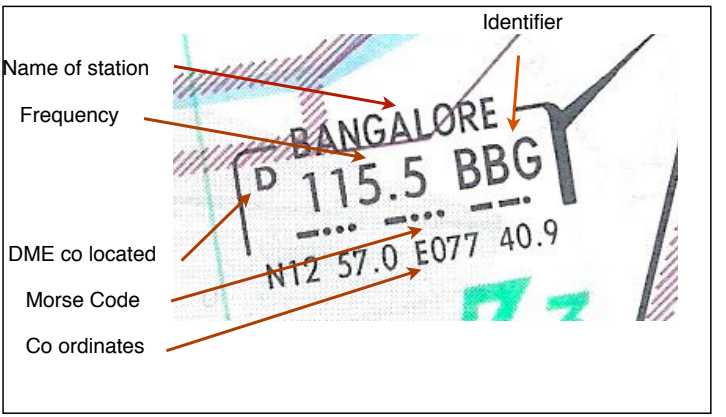
5.27.3 **Airborne Equipment Errors.** Caused by aircraft equipment while converting phase differences to bearings resulting in errors up to $\pm$ 3 °.

5.28 The aggregate of all errors can give a total error of $\pm$ 5 °. In addition to these errors, pilotage errors also may be induced specially as the aircraft approaches the beacon.

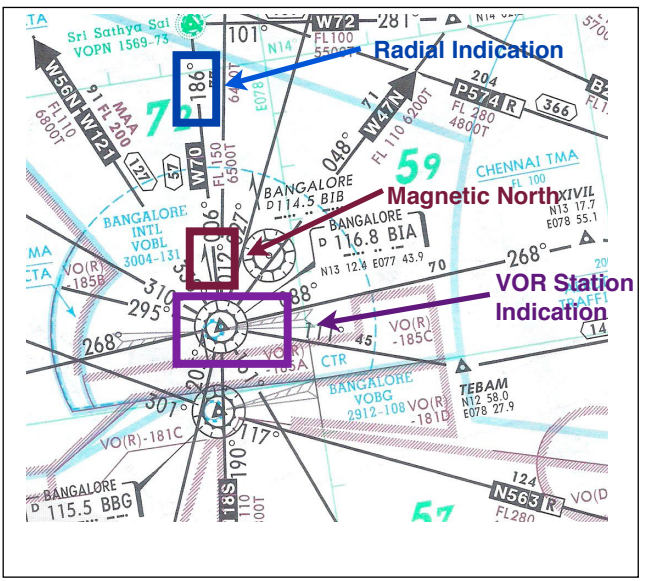
Chart Depiction

5.29 The VOR beacons are depicted in the navigation charts is as given in the figure:-

Figure 5.7



5.30 A detailed chart is presented in the following figure **Figure 5.8**



Usage of VOR

5.31 In order to use the VOR for navigation:

5.31.1 tune to the proper frequency

5.31.2 identify the VOR using the Morse Code identifier

5.31.3 make sure the signal strength is sufficient (no Off flag)

5.31.4 turn the OBS to the desired course

Accuracy Check

5.32 In many airports, there are designated points at which the accuracy of the equipment can be done. Usually at holding points. There is a sign on the ground indicating the radial and distance of the holding point. The aircraft equipment can be cross checked while parking at this spot. It is shown as in the following figure.

BBG 115.5 243/1.2

Summary

5.33 In this chapter, we learnt the principles of operation, ground and airborne equipment, errors and chart depiction of the VOR. In the next chapter we shall learn about the practical usage of the aid while flying.