

Operational Notes on VHF Omni Range (VOR) Contents

Disclaimer

These notes are a reproduction of a booklet originally published by the Civil Aviation Authority. Although these notes are no longer in print, they continue to provide a valuable resource and are made available as reference material for students, pilots and instructors. The notes have not been edited, and as they were written 20 or more years ago, may contain information relating to systems that are no longer in production or have been modernised.

1. Introduction	1-1
2. Principle of Operation	2-1
3. Airborne Equipment	3-1
4. Operational Use.....	4-1
5. VOR Errors	5-1
5.1 Ground Station Error	5-2
5.2 Site Effect Error	5-3
5.3 Vertical Polarisation (Attitude Effects).....	5-4
5.4 Airborne Equipment Error	5-5
5.5 Aggregate Error	5-6
6. Summary	6-1

Operational Notes on VHF Omni Range (VOR)

1. Introduction

The VHF Omni-directional Radio Range, the abbreviations for which are 'VOR' and 'Omni', enables a pilot to determine the direction of his aircraft from any position to or from a VOR beacon, and, if necessary, track to or from the beacon on a selected bearing. VOR is a Very High Frequency (VHF) navigation aid which operates, in Australia, in the 112.1 to 117.9 megacycles (mcs) frequency band. Because it is a VHF aid, its ground to air range is limited to 'line of sight' reception which is typical of VHF transmission. The range achieved is dependent, therefore, on the siting of the VOR beacon with relation to surrounding terrain, and on the height at which the aircraft is flying. (See *Figure 1*).

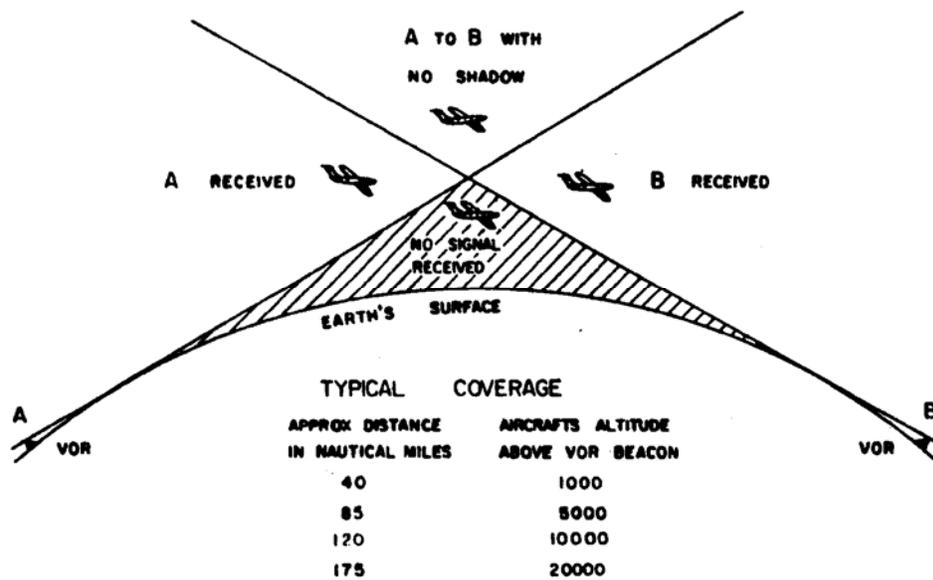


Figure 1. The VHF Omni-directional Radio Range

As a VHF navigation aid, the VOR is static-free, and the information given by it is displayed visually on easily read and interpreted cockpit instruments. An infinite number of bearings can be obtained and they may be visualized as radiating from the beacon like spokes from the hub of a wheel. However, for practical purposes the number of bearings can be considered to be limited to 360, one degree apart, and these 360 bearings are known as radials. A **Radial** is identified by its **magnetic bearing** outbound from the **VOR** beacon.

Operational Notes on VHF Omni Range (VOR)

2. Principle of Operation

The basic principle on which a VOR operates can be understood from a study of a simple analogous optical system which is illustrated at *Figure 2*. Assume that there are two lights located at the same position, one of which is a rotating green light which is only seen when the beam is directed at an observer, and the other a white light which is visible from all directions. The green light rotates at 10 degrees per second, that is, it completes a revolution in 36 seconds, and, when it is directed to magnetic north, it trips a switch to cause the white light to flash momentarily. An observer with a stop watch can note the time interval between a white flash and the next green flash, and, knowing the angular rate of the rotating green light, can determine his bearing from the lights. For example, if the observer sees the green light 10 seconds after a white flash, then the observer is on a bearing of 100° magnetic from the lights, that is, the 100° radial. The observer's bearing to the lights is, of course, the reciprocal of 100°, viz., 280°.

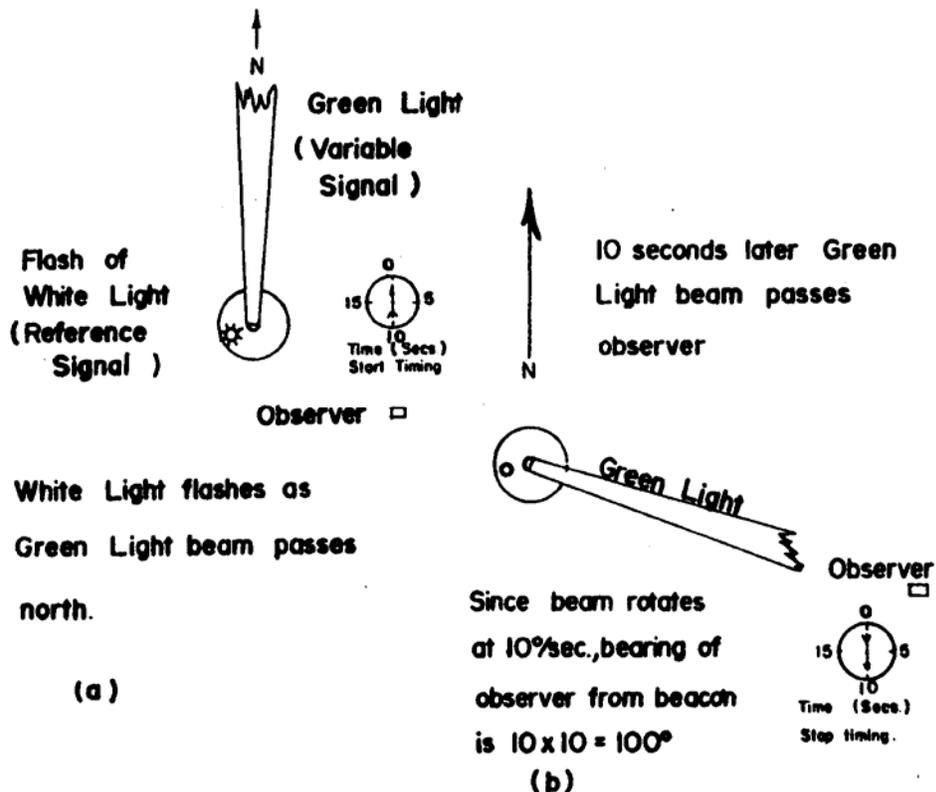


Figure 2. Analogous Optical System



Operational Notes on VHF Omni Range (VOR)

2. Principle of Operation

Instead of light signals, the VOR beacon transmits two VHF radio signals from the same facility. One of these signals, analogous to the white light, called the reference phase, is omni-directional and radiates from the station in a circular pattern. The phase of this signal is constant through 360° of azimuth. The other signal, analogous to the green light, is transmitted as a rotating field. This signal pattern rotates uniformly at 1800 r.p.m., varies in phase with azimuth, and is called the variable phase. Therefore, there is a different phase of this signal at each separate point around the station.

Magnetic north is used as the baseline for measuring the phase relationship between the reference and variable signals. The two signals are aligned so that at magnetic north they are exactly in phase. As can be seen in *Figure 3*, a phase difference, which is analogous to the time difference between the white flash and sighting the green light, exists at any other point of azimuth around the beacon. This phase difference is measured electronically and converted to degrees of angle by the aircraft airborne equipment thus identifying the aircraft position in azimuth around the beacon. The information is presented visually by an indicator on the instrument panel.

An identification signal of two or three Morse Code letters is transmitted by the VOR beacon every ten seconds. It is also possible to transmit voice identification or other information, that is, meteorological information.



Operational Notes on VHF Omni Range (VOR)

2. Principle of Operation

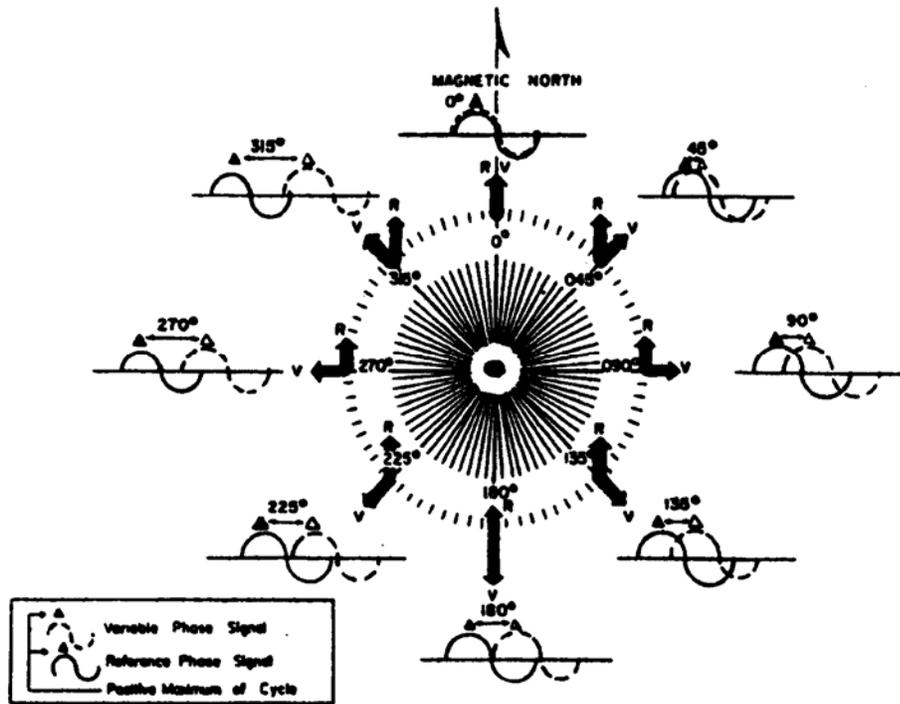


Figure 3. VOR Phase Angle Relationships

Operational Notes on VHF Omni Range (VOR)

3. Airborne Equipment

There are many different types of airborne equipment of different degrees of complexity available. However, all equipments have the following component parts, viz., an Antenna, a Control Box, a Receiver, and Navigation Circuits, (including Visual Indicator). In this section it is intended to deal with the airborne equipment in a general manner to describe basic principles of function and operation. Pilots should study the manuals applicable to the particular equipment they may be required to use. More detailed general information on the operation of airborne equipment is contained in Appendix 2.

The Antenna is a V-type dipole antenna.

The Control Box contains an ON-OFF switch, a frequency selector or tuner, and an aural volume control. The volume control regulates only the intensity of the signals going into the headset or the loudspeaker.

The Receiver is a conventional superheterodyne receiver.

The Navigation Circuits take the signals from the receiver, and measure the phase angle difference between the reference signal and the variable signal. As the phase angle difference is a definite fixed amount for each radial, it is therefore possible to determine the bearing of the aircraft from the VOR beacon, and this information can be presented visually. Similarly, if the equipment can be adjusted to a desired bearing (or phase angle difference) and indicate the relationship of the aircraft to the bearing and when the aircraft has reached the bearing, it is possible to preset tracks and then fly to and continue along them. The visual indicators comprise a manually operated Omni Bearing Selector, a Deviation Indicator, and a TO/FROM Indicator, and these are normally combined in one instrument known as an Omni Bearing Indicator. The information available from the navigation circuits is presented on the Deviation Indicator and the TO/FROM Indicator with relation to the setting of the Omni Bearing Selector. Information derived from the VOR may also be presented on a Radio Magnetic Indicator.

A block diagram of the airborne equipment is shown at *Figure 4* and an Omni Bearing Indicator is illustrated at *Figure 5*.



Operational Notes on VHF Omni Range (VOR)

4. Operational Use

The VOR enables a pilot to select, identify, and locate a line of position from a particular VOR beacon. The following information can be obtained:

- The magnetic bearing of the aircraft from the VOR beacon
- The magnetic bearing from the aircraft to the VOR beacon
- The position of the aircraft, that is, port or starboard, of a selected radial
- When the aircraft is closing and when it is flying along a selected radial
- When the aircraft passes over the VOR beacon.

All the procedures detailed in this section are applicable to aircraft fitted with an Omni Bearing Indicator.

Tuning and Orientation

To tune the VOR equipment, turn on the power switch, select the required frequency, and adjust the volume until the VOR beacon aural identification signal can be clearly heard and **identified** as the required beacon. Ensure that the OFF alarm flag has disappeared as this indicates that the visual indicators are serviceable. Now turn the Omni Bearing Selector (OBS) until the Deviation Indicator is centred and TO is shown by the TO/FROM indicator. The bearing then shown in the Bearing Selector Window is the magnetic bearing to the VOR beacon.

Homing Directly to the VOR Beacon

After orienting the aircraft as detailed above, turn the aircraft onto the magnetic heading shown in the Bearing Selector Window and then, changing heading as necessary, maintain the Deviation Indicator in the central position. With the TO/FROM Indicator showing TO, the aircraft heading should be changed toward the Deviation Indicator to re-centre it if it deviates from the central position as the Deviation Indicator shows the position of the Radial relative to the aircraft position. If a cross-wind component exists, this will be indicated by the



Operational Notes on VHF Omni Range (VOR)

4. Operational Use

Deviation Indicator's moving to the side from which the wind is blowing. The drift angle is the difference between the aircraft heading necessary to maintain the Deviation Indicator in the central position, and the bearing being maintained.

Note: The Radial is the reciprocal of the bearing being maintained (see Figure 6).

Continue flying with the Deviation Indicator central along the bearing towards the VOR beacon until the Deviation Indicator swings from side to side. The aircraft is now over the VOR beacon, and, if flight is continued on the same heading the Deviation Indicator will return to the central position and the TO/FROM indicator will show FROM.

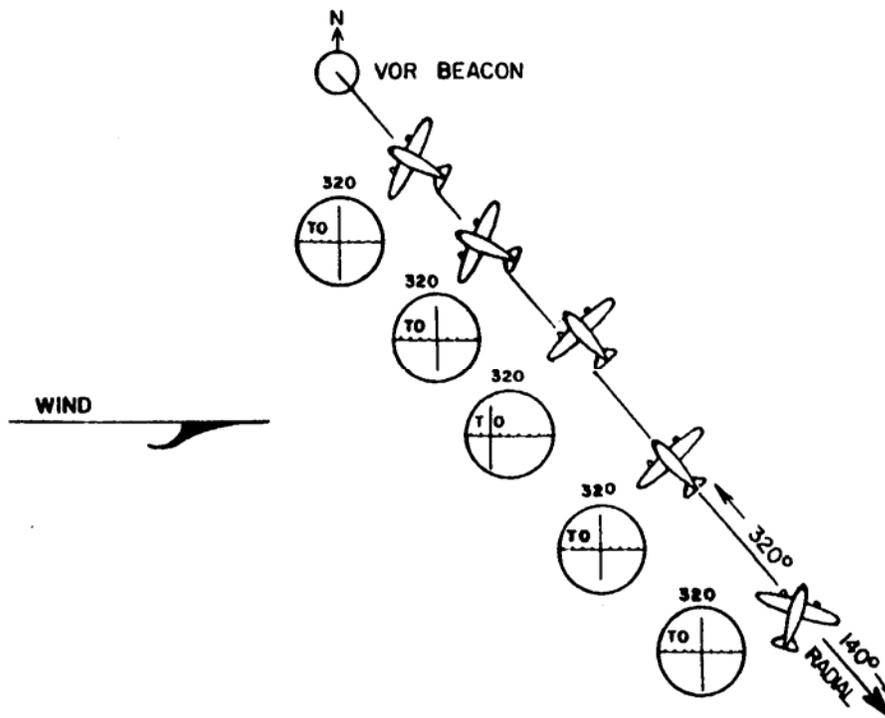


Figure 6. Homing Directly to the Beacon



Operational Notes on VHF Omni Range (VOR)

4. Operational Use

Interception of an Inbound Track

Tune and identify the required VOR beacon and orient the aircraft to ascertain the magnetic bearing of the aircraft to the beacon. Then rotate the OBS until the required inbound track is shown in the Bearing Selector Window. The TO indicator should then be visible (If FROM appears, either the wrong track has been set or the aircraft is on the other side of, or has passed the beacon—see *Interception of an Outbound Track*). The aircraft should then be turned in the direction of the Deviation Indicator on to a suitable intercept heading, which is determined from the position of the aircraft as visualised from the information available from the orientation. Closure of the required track is shown by the Deviation Indicator moving towards the central position, and when this occurs, the aircraft should be turned onto the same heading as the required inbound track (see *Figure 7*). The track should be maintained as described in *Homing Directly to the VOR Beacon*.

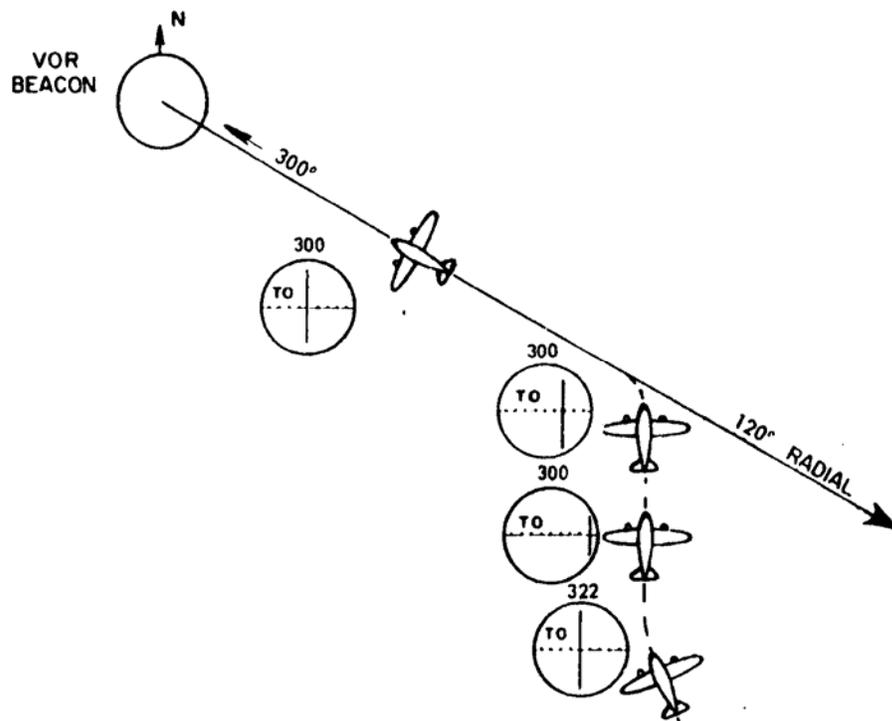


Figure 7. Intercepting a Track Inbound



Operational Notes on VHF Omni Range (VOR)

4. Operational Use

Interception of an Outbound Track

The procedure for intercepting an outbound track differs from the procedure for intercepting an inbound track only in that FROM rather than TO appears in the TO/FROM Window (see Figure 8).

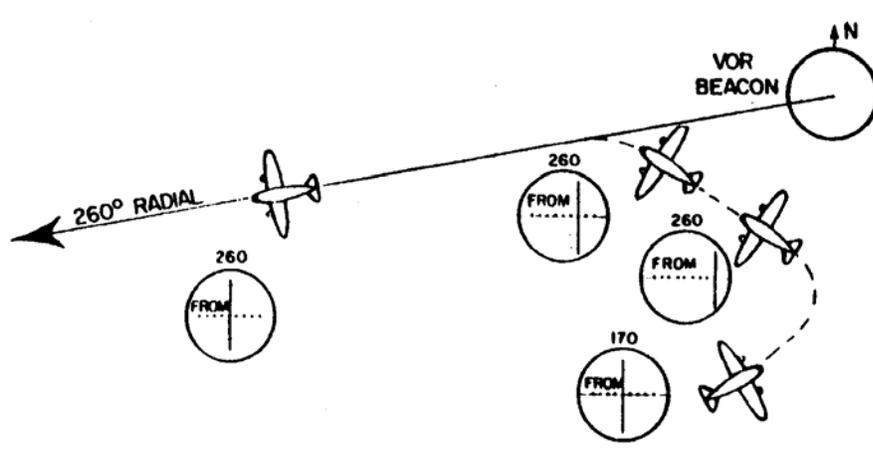


Figure 8. Intercepting a Track Outbound



Operational Notes on VHF Omni Range (VOR)

4. Operational Use

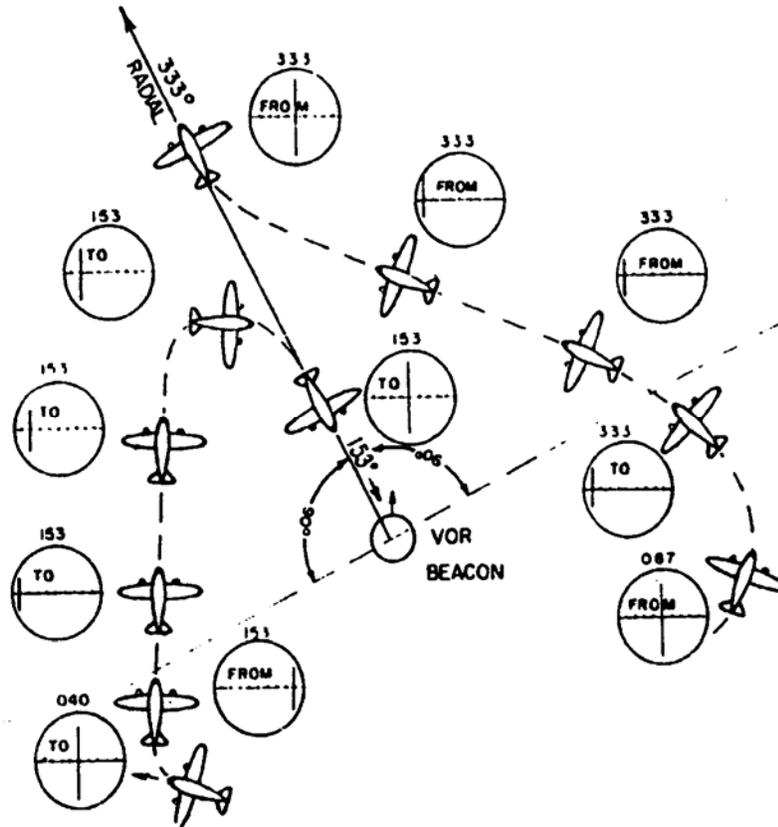


Figure 9. Orienting the Aircraft to Intercept a Track

NOTE: If, when orienting the aircraft to intercept an inbound or an outbound track it is found that the aircraft is on a bearing which is 90 degrees or more removed from the required track, then the TO/FROM indications as specified in the paragraphs *Interception of an Inbound Track* and *Interception of an Outbound Track*, will not apply until the aircraft is within a sector 90 degrees on either side of the required track (see Figure 9).

Holding

When holding in the conventional racetrack pattern, it must be appreciated that the outbound leg of the pattern is **not** via a radial, but parallel to and on the reciprocal track to the inbound leg which is



Operational Notes on VHF Omni Range (VOR)

4. Operational Use

almost invariably on a designated radial. Therefore on reaching the holding point to commence the pattern, the inbound track is set by the OBS, and this setting is retained while flying in the holding pattern. This setting will provide information to intercept the inbound track when turning inbound at the end of the outbound leg.

Instrument Descent Procedure

After passing over the station, set the OBS to the published outbound track and fly this track outbound, descending if necessary, until the commencement of the procedure turn. During the procedure turn, set the OBS to the published inbound track. Intercept this track and continue descent to the minimum altitude, maintaining the inbound track by reference to the Deviation Indicator. If a missed approach is necessary, carry out the missed approach in the manner specified in the missed approach procedure, and if a change of track is prescribed, re-set the OBS to the required track at the point specified for change of track in the procedure.



Operational Notes on VHF Omni Range (VOR)

5. VOR Errors

Errors are likely to exist in any VOR system due to a number of causes. These include ground station error, site effect error, error due to vertical polarisation effects and airborne equipment error. The algebraic sum of all these errors is known as the aggregate error. Each of these errors will be explained individually to give a better understanding of the limitations of the system, although, from an operational view point, the pilot is concerned primarily with the aggregate error.



Operational Notes on VHF Omni Range (VOR)

5. VOR Errors

5.1 Ground Station Error

This is a systematic error associated with the transmitter, aerial and earth systems and power supply that is with the actual ground equipment. Error on a particular bearing is very small, and is plotted accurately on commissioning. It is similar to quadrantal error in an airborne ADF system. Ground station error, in practice, is usually less than $\pm 2^\circ$.



Operational Notes on VHF Omni Range (VOR)

5. VOR Errors

5.2 Site Effect Error

There are, superimposed on the ground station error, site effects which are due to topographical features near the ground station. These site effects modify the ground station errors. The combined effect of these errors are determined at various altitudes at the time of commissioning and the overall error must be less than $\pm 3^\circ$.

Terrain effects caused by the VOR radials being distorted by signals reflected from rough terrain may be experienced under certain circumstances. These effects are evidenced in the form of slow or quick oscillations of the deviation indicator. The VOR track is said to band or scallop depending on the rate of oscillation. Bends on VOR radials normally do not exceed 2° from the average alignment of the track and the scalloping amplitude must be less than $\pm 2^\circ$.



Operational Notes on VHF Omni Range (VOR)

5. VOR Errors

5.3 Vertical Polarisation (Attitude Effects)

If vertical polarisation effects are presented they are detected in manoeuvres which tilt the aircraft aerial, that is in a turn by an aircraft. When in a banked attitude, the receiving antenna on the aircraft, instead of sampling only the horizontally polarised VOR signals, may pick up large sloping obstructions. Under these circumstances, the deviation indicator is seen to move abnormally in either direction, thus giving rise to incorrect guidance information.

In the type of VOR ground equipment installed in Australia, the vertical component actually radiated by the beacon is very small, hence this form of interference will be rarely encountered in practice.



Operational Notes on VHF Omni Range (VOR)

5. VOR Errors

5.4 Airborne Equipment Error

As the name implies, airborne equipment error is the error attributable to the various components of the VOR equipment in the aircraft. In well designed and built equipment it is generally less than $\pm 2^\circ$.



Operational Notes on VHF Omni Range (VOR)

5. VOR Errors

5.5 Aggregate Error

The algebraic sum of all the errors mentioned above is known as the aggregate error. It should be appreciated that procurement of precise figures on aggregate error, even on a probability basis, is extremely difficult if not impossible. However, the purpose in explaining the presence of these errors is to illustrate that the VOR is **not a precision aid**. It will be found that, in practice, aggregate errors greater than $\pm 5^\circ$ are seldom encountered. It should be appreciated, too, that factors for aggregate error and for pilot error are used in the determination of standards used for aircraft separation purposes.



Operational Notes on VHF Omni Range (VOR)

6. Summary

It is essential to remember the following points concerning the VOR and its operation:

- A radial is a magnetic bearing **from** the VOR beacon
- The Deviation Indicator can be centred on either of two bearings by the OBS. These bearings will be 180° apart with the ambiguity automatically resolved by the TO/FROM indicator
- The VOR system, in practice, should be considered to be accurate only to the order of $\pm 5^\circ$
- As the VOR propagation is 'line of sight', the distance at which a VOR beacon can be received increases with aircraft elevation above the beacon
- The VOR beacon **must** be identified aurally before information derived from the beacon is used
- The Omni Bearing Indicator always indicates magnetic bearings TO or FROM the VOR beacon—never relative bearings
- Heading of the aircraft at any instant does not affect VOR bearings. The bearing obtained depends on the aircraft location with relation to the VOR beacon
- Bearing selection by the OBS is by 1 degree intervals. When a bearing is selected, full travel of the Deviation Indicator from one side to the other represents 20° of azimuth, that is 10° either side of the selected bearing.

