Chapter 10  Navigation

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VHF Omnidirectional Range (VOR)

The **VHF Omnidirectional Range (VOR)** is the backbone of the National Airway System, and this radio aid to navigation (**NAVAID**) provides guidance to pilots operating under visual flight rules as well as those flying instruments.

On sectional aeronautical charts, VOR locations are shown by blue symbols centered in a blue compass rose which is oriented to Magnetic North. A blue identification box adjacent to the VOR symbol lists the name and frequency of the facility, its three-letter identifier and Morse Code equivalent, and other information as appropriate. For example: a small solid blue square in the bottom right hand corner indicates Hazardous Inflight Weather Advisory Service (HIWAS) are available. See the “Radio Aids to Navigation and Communications Box” information in FAA Legend 1.

Some VORs have a voice identification alternating with the Morse Code identifier. Absence of the identifier indicates the facility is unreliable or undergoing routine maintenance; in either case, it should not be used for navigation. Some VORs also transmit a T-E-S-T code when undergoing maintenance.

The VOR station continuously transmits navigation signals, providing 360 magnetic courses to or radials from the station. Courses are TO the station and radials are FROM the station.

TACAN, a military system which provides directional guidance, also informs the pilot of the aircraft’s distance from the TACAN Station. When a VOR and
a TACAN are co-located, the facility is called a VORTAC. Civil pilots may receive both azimuth and distance information from a VORTAC.

At some VOR sites, additional equipment has been installed to provide pilots with distance information. Such an installation is termed a VOR/DME (for “distance measuring equipment”).

**VOR Orientation**

Cockpit display of VOR information is by means of an indicator as shown in Figure 10-1.

The **Omni Bearing Selector (OBS)** is an azimuth dial which can be rotated to select a course or to determine which radial the aircraft is on. The **TO/FROM indicator** shows whether flying the selected course would take the aircraft to or from the VOR station. A TO indication shows the radial selected is on the far side of the VOR station, while a FROM indication means the aircraft and the selected course are on the same side.

The **Course Deviation Indicator (CDI)**, when centered, indicates the aircraft is on the selected course, or, when not centered, whether that course is to the left or right of the aircraft. For example, Figure 10-2 is indicating that a course of 030° would take the aircraft to the selected station, and to get on that course, the aircraft would have to fly to the left of 030°.

To determine position in relation to one or more VOR stations, first tune and identify the selected station. Next, rotate the OBS until the CDI centers with a FROM indication. The OBS reading is the magnetic course from the VOR station to the aircraft. With reference to Figure 10-3, the line of position is established on the 265° radial of the XYZ VOR.

Repeat the procedure using a second VOR. The aircraft is located at the point where the two lines of position cross. See Figure 10-4.
Figure 10-1. The VOR indicator

Figure 10-2. Interpreting the OBS and CDI indications
Course Determination

To determine the course to be flown to a VOR station on the sectional aeronautical chart, first draw a line from the starting point to the VOR symbol in the center of the compass rose. At the point where the course line crosses the compass rose, read the radial. The course to the station is the reciprocal of that radial. See Figure 10-5.
The routes established between VORs are depicted by blue-tinted bands showing the airway number following the letter “V,” and are called “Victor airways.” See Figure 10-6.

When approaching a VOR where airways converge, a pilot must exercise extreme vigilance for other aircraft. In addition, when climbing or descending VFR on an airway, it is considered good operating practice to execute gentle banks left and right for continuous visual scanning of the airspace.

VOR receiver accuracy may be checked by means of a VOR Test Facility (VOT), ground check points, or airborne check points.
VOTs transmit only the 360° radial signal. Thus, when the OBS is set to 360°, the CDI will center with a FROM indication; while the reciprocal, 180°, will cause the CDI to center with a TO indication. An accuracy factor of plus or minus 4° is allowed when using a VOT facility.

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**Automatic Direction Finder (ADF)**

The **Automatic Direction Finder (ADF)** consists of a receiver that receives radio waves in the low- and medium-frequency bands and an instrument needle that points to the station. Some ADF indicators have a compass card that remains in a fixed position, while in others, the compass card turns as the aircraft turns. This is called a **Radio Magnetic Indicator (RMI)**.

An instrument with a fixed-compass card (fixed-scale) will always show zero degrees at the nose of the aircraft (Figure 10-7). The actual magnetic heading must be obtained from the magnetic compass or other heading indicator.

ADF indicators which have rotating compass cards (RMIs) allow the pilot to read the magnetic heading of the aircraft directly without referring to another instrument (Figure 10-8).

The ADF may be used to either home or track to a station. ADF **homing** is flying the aircraft on any heading required to keep the azimuth needle pointing directly in front of the aircraft until the station is reached. **Tracking** is following a straight geographic path by establishing a heading that will maintain the desired track over the ground regardless of wind effect.

On an indicator with a fixed card, the azimuth needle, pointing to the selected station indicates the angular difference between the aircraft heading and the direction to the station, measured clockwise from the nose of the aircraft. This angular difference is the **relative bearing (RB)** to the station, and may be read directly from a fixed-scale indicator. For example, in Figure 10-7, the relative bearing to the station is 135°.

If the indicator has a rotating scale, the number of degrees clockwise from the nose of the aircraft to the head of the needle must be determined. In Figure 10-8, the relative bearing is 025°.

The direction the aircraft should fly to arrive at the selected station is the **magnetic bearing (MB)**. The magnetic bearing to the station may be read
directly from an indicator with a rotating scale. In Figure 10-8, the magnetic bearing to the selected station is 295°, as shown by the head of the needle; and the bearing from the station (115° in this example) may be read under the tail of the needle.

When the indicator has a fixed scale, computation is necessary to determine the magnetic bearing to the selected station. The ADF formula is:

Magnetic Heading (MH) + Relative Bearing (RB) = Magnetic Bearing to the Station (MB)

Problem:

What is the magnetic bearing TO the station using the ADF in Figure 10-9?
Solution:

1. MH (350°) + RB (315°) = MB (665°)

2. If the sum is greater than 360, subtract 360:

\[
\begin{align*}
665° \\
-360° \\
\hline
305°
\end{align*}
\]

In this case, the magnetic bearing FROM the station would be 125°, which is the reciprocal of 305°.

ADF orientation and tracking procedures are used when intercepting a specific inbound or outbound magnetic bearing. With an aircraft on a magnetic heading of 270° and a relative bearing to the station of 290°, indications would appear as shown in Figure 10-10.

To intercept an inbound magnetic bearing with the indications shown in Figure 10-10, the following steps can be used:

1. If it is desired to intercept the 180° magnetic bearing to the station, turn to parallel the desired inbound bearing.

2. Note whether the station is to the right or left of the nose of the aircraft and determine the number of degrees of needle deflection. In this example, the ADF needle is pointing 20° to the right of the nose of the aircraft. Double the amount of needle deflection to find the interception angle: 40°.

3. Turn the aircraft toward the desired magnetic bearing the number of degrees determined (40°) for the interception angle.

4. If using an ADF with a fixed scale, maintain the intercept heading until the needle is deflected the same number of degrees from the nose of the aircraft as the angle of interception. At that time, the desired magnetic bearing to the station, 180°, has been intercepted. Turn inbound and track to the station.

5. If using an ADF with a rotating scale, maintain the intercept heading until the needle points to the desired magnetic bearing to the station of 180°. Turn inbound and track to the station.
Global Positioning System (GPS)

GPS is a United States satellite-based radio navigational, positioning, and time transfer system operated by the Department of Defense (DOD). The system provides highly accurate position and velocity information and precise time on a continuous global basis to an unlimited number of
properly-equipped users. The GPS constellation of satellites is designed so that a minimum of five are always observable by a user anywhere on earth. The GPS receiver uses data from a minimum of four satellites to yield a three dimensional position (latitude, longitude, and altitude) and time solution.