

## Ground Lesson: Radio Navigation

### Objectives:

1. to understand basic navigational equipment and it's usage

### Justification:

1. radio navigation is a primary means of cross country navigation
2. knowledge of, and proper execution of cross country flights is required for the private pilot checkride.

### Schedule:

Activity	Est. Time
Ground	1.5
<b>Total</b>	<b>1.5</b>

### Elements Ground:

- VOR Navigation
- DME
- ADF Navigation
- Advanced Navigation
- Loran-C
- GPS

### Completion Standards:

3. when the student is able to navigate using radio navigation and GPS

## Presentation Ground:

### VOR Navigation

#### 1. Very High Frequency Omnidirectional Range (VOR) Navigation

- (1) ground equipment
  - i. 360° radials emitting from station like the spokes on a wheel
    - (i) accuracy is within  $\pm 1^\circ$
    - (ii) degrees are oriented with magnetic north
  - ii. frequency range from 108.00 - 117.95 MHz
  - iii. Each station has a three letter morse code identifier to:
    - (i) identify correct frequency usage (may take up to 20 seconds to hear ident)
    - (ii) check station online
    - (iii) check to see if signal is reliable
  - iv. restricted to line of sight
  - v. Three types of VOR's with different ranges (optional)
    - (i) Terminal VOR (TVOR) - within 25NM, below 12,000 AGL
    - (ii) low altitude VOR (LVOR) - up to 40NM between 1,000 and 18,000 AGL
    - (iii) high altitude VOR (HVOR) - up to 40NM up to 14,500, 100NM between 14,500 and 18,000, 130NM between 18,000 and FL450, 100NM between FL450 and FL600
- (2) aircraft equipment
  - i. VOR receiver - where you tune in the frequency
  - ii. VOR indicator - instrument which visually displays course information received from the receiver; main components are
    - (i) to-from-off flags
    - (ii) omnibearing selector (OBS)
    - (iii) course deviation indicator (CDI)
  - iii. VOR antenna
- (3) usage
  - i. find radial **from** or course **to** VOR
    - (i) tune in VOR and rotate OBS until CDI centers. from flag is radial, to flag is course
  - ii. tracking to and from VOR
    - (i) intercept radial using an appropriate intercept angle
    - (ii) upon intercept, turn to correct heading and track CDI changes
    - (iii) correct CDI deviations via WCA to correct for drift
  - iii. cross checking position
    - (i) using 2 VORs you can determine accurately your location
    - (ii) using method (i), select radial **from** for 2 different VORs
    - (iii) draw extensions of the 2 radials until intersection.
- (4) notes
  - i. reverse sensing - situation in which the VOR indicator is set to the reciprocal of the desired course. In this case, the CDI deflections will be reversed.
  - ii. off indication - can occur when the aircraft is directly over the station or when the VOR station signal is unreliable.
  - iii. cone of confusion - area above the VOR station where you may see an off flag and erratic CDI indications. smaller as you get closer (vertically) to the station.

iv. VOR accuracy - via ground or air checkpoints, or by checking two VOR indicators against each other, you can determine the accuracy of the VOR instruments ( $\pm 4^\circ$  is acceptable)

## 2. Distance Measuring Equipment (DME)

- (1) supplemental VOR navigational instrument that allows readings of distance from a VOR station
  - i. two types of stations allow DME - VORTAC and VOR-DME
  - ii. although it is usually paired to the VOR receiver, it is a separate piece of equipment with a separate antenna
  - iii. identify works in similar fashion as VOR except occurs every 30 seconds
- (2) distance reading is slant range, thus at 6,000 ft, over the station, reading = 1NM
- (3) allows position fix with only one VOR, using radial + distance to define fix
- (4) some receivers have ETA information

## ADF Navigation

### 3. Automatic Direction Finder (ADF) Navigation

- (1) ground equipment
  - i. nondirectional radio beacons (NDB) transmit between 190 Khz and 535 Khz
  - ii. have three letter identifier for similar reasons to VOR
  - iii. *not* restricted to line of sight
  - iv. commercial broadcast stations (BS) can be used as well
- (2) aircraft equipment
  - i. ADF antenna - directional antenna and sense antenna
  - ii. ADF receiver - where you can tune and identify NDBs
  - iii. ADF bearing indicator - provides visual representation of horizontal relative bearing to station (in relation to aircraft)
    - (i)  $MH + RB = MB$  to station
- (3) usage
  - i. find radial off of NDB or BS
    - (i) tune in to NDB or BS and read the tail end of the ADF indicator once it stabilizes
  - ii. track to/from station
    - (i) tune in to NDB or BS and turn towards the station until head of indicator points at the 0 (or top) of the ADF indicator.
    - (ii) adjust as necessary for wind correction
      - a. heading *to* the station, indicator will show WCA, opposite direction of wind
      - b. heading *from* the station, indicator will show WCA, same direction of wind
- (4) notes
  - i. limitations
    - (i) subject to many interferences including storms, mountains, ocean shoreline, atmosphere
    - (ii) no flag on ADF indicator, so no way to know of reliable signal except via ident
  - ii. HI accuracy when using NDB
    - (i) since the range of NDBs can be much higher than VOR, accurate HI settings are crucial. If not, a small deflection (when far away) may mean aircraft is far off course

## iii. movable card indicator and RMI

- (i) movable card indicator can rotate the indicator card to set heading to current heading
- (ii) RMI is like a movable card, but indicator card rotates automatically

**Advanced Navigation**1. Loran - Long Range Navigation

- (1) navigation system based on ground stations which calculate differences in arrival times of pulses between “chains” of stations
- (2) a chain consists of 1 master and at least 2 secondary stations (which is the minimum required for navigation)
- (3) stations broadcast on low frequencies 90 - 110 Khz
- (4) advantages:
  - i. highly accurate to within  $\frac{1}{4}$  NM of actual position
  - ii. Loran receivers usually contain databases of most major waypoints (airports, intersections, etc), and also accommodate pilot waypoints (lat + long)
  - iii. a station signal is usable for hundreds of miles
- (5) disadvantages:
  - i. affected by weather, electrical disturbances, precipitation and even dust
- (6) being phased out in favor of GPS

2. Global Positioning System (GPS)

- (1) satellite based navigation system which uses multiple satellite information to determine position for the receiver
  - i. minimum of 4 satellites are required for 3D position (lat, long, alt)
  - ii. minimum of 3 satellites are required for 2D position (lat, long)
  - iii. some receivers can access up to 12 satellites at one time
- (2) There are over 26 satellites in the GPS system
- (3) advantages:
  - i. highly accurate to within hundreds of feet. With WAAS (Wide Area Augmentation System) accurate to within 6 ft; and with Differential GPS, to within 1 cm
    - (i) both WAAS and DGPS augment the satellites with ground based stations
  - ii. extensive databases with most major waypoints
  - iii. easy to use
  - iv. certain GPS receivers are approved as primary navigation for VFR and IFR
- (4) disadvantages:
  - i. pilot may become dependent on GPS, neglecting alternative means of navigation, even for cross check purposes.