Navigation Systems

Objective

To understand how the navigation systems installed in our aircraft work and how to use them to navigate, also to understand radar services that are available to us.

Motivation

Pilots rely on navigation systems to fly to unfamiliar locations, making it essential for cross-country flying. Understanding radar services provided by ATC is also important for safety and efficiency.

Overview

- Radio Navigation
  - Principle of Operation
  - Frequency Ranges
  - Types of Navigation Systems (VOR, NDB, DME)
- Flying with Radio Navigation
  - Tuning and IDing Stations
  - CDIs and HSIs
  - Intercepting a Course or Radial
- Transponders
- ADS-B
- GPS
- EFB
- Radar Services

Radio Navigation

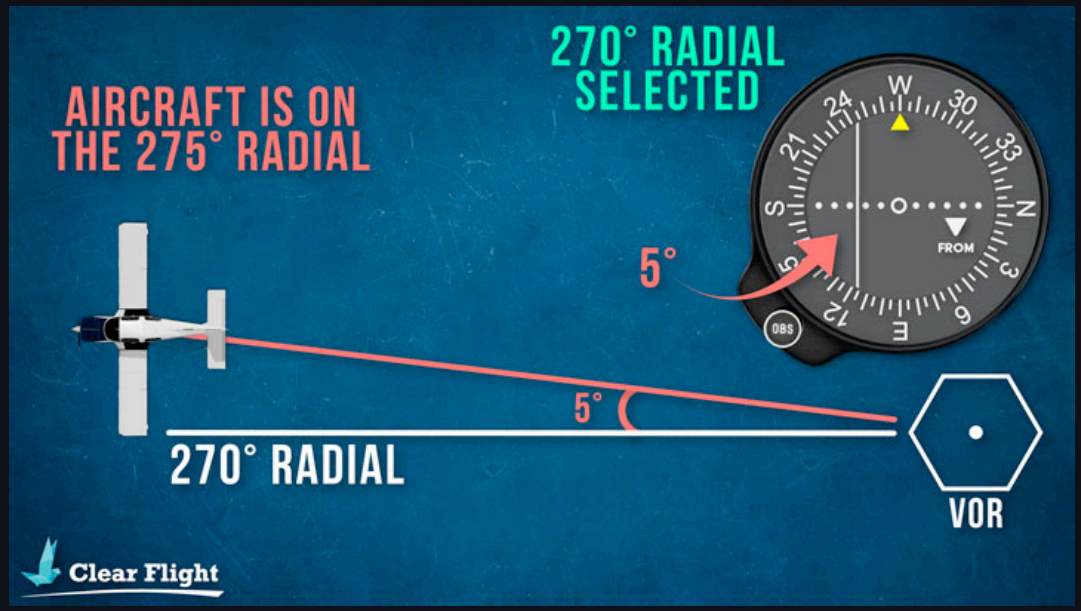
Principle of Operation

- Ground navigation stations emit radio signals
- Equipment on the aircraft receives these signals and interprets them
- Operates on different frequency ranges
  - LF, Low Frequency: NDB
  - VHF, Very High Frequency (108 - 136 Mhz): VOR, LOC, Radio Communications
  - UHF, Ultra High Frequency (Above 800 Mhz): Glideslope and GPS
  - Radar (Above 900 Mhz): Transponder, DME.

VHF Omnidirectional Range (VOR)

- Ground-station which broadcasts two VHF signals
- Emits two signals:
  - Reference signal (the 360 radial)
  - Variable signal (modulates as it sweeps around magnetic north)
- VOR receiver on the aircraft compares the two signals and determines the bearing to the station
- Limited to line-of-sight from the station

VOR in the Cockpit



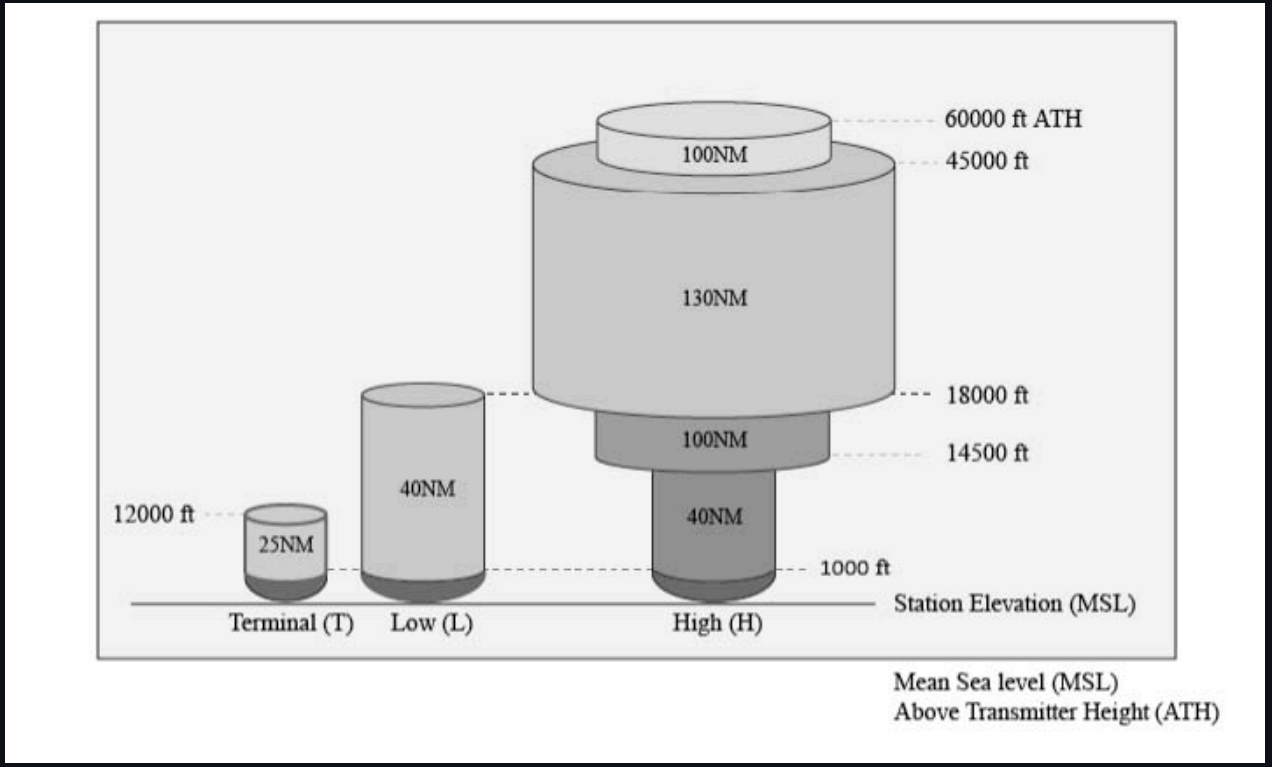
- Course deviation indicator (CDI) shows the angular difference between the CDI's selected bearing and the aircraft's current bearing
- Makes it easy to track to or from a VOR station on a specific radial

Flavors of VORs

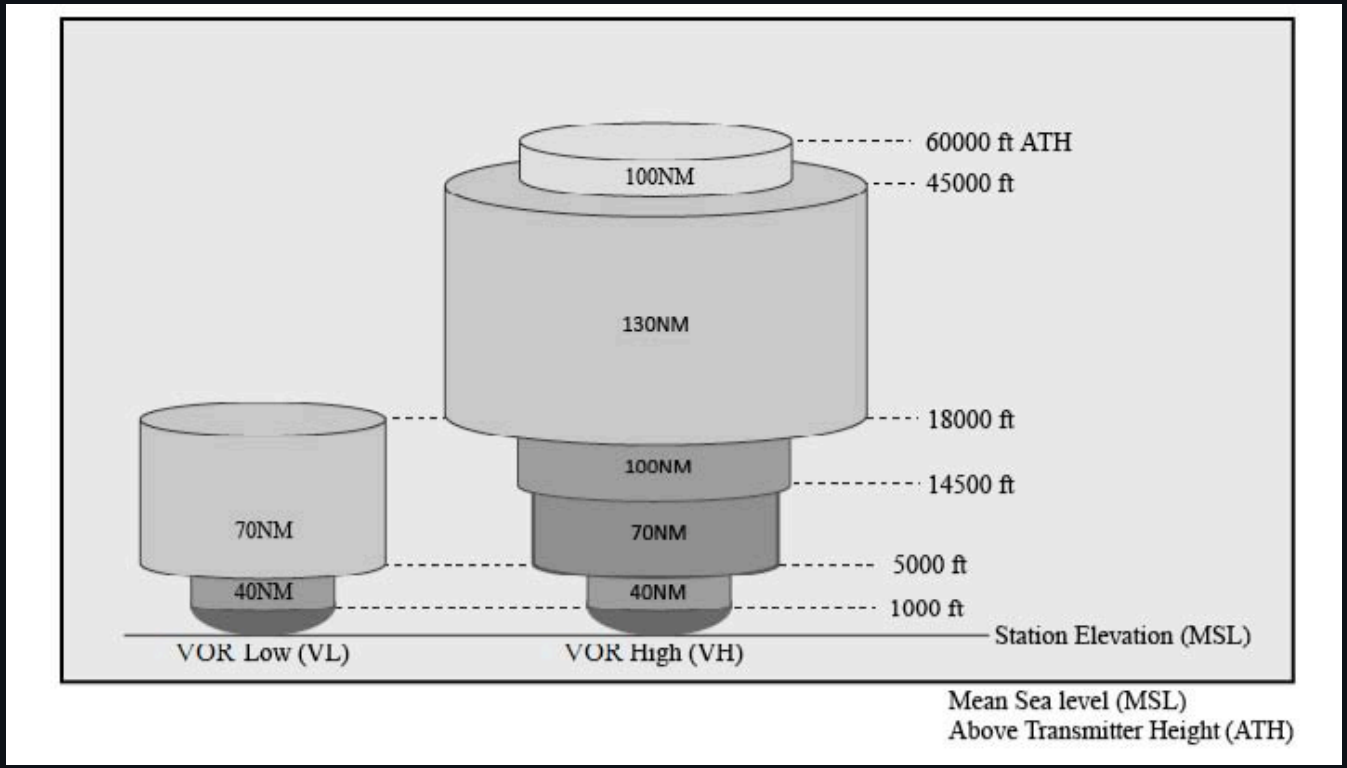
- VOR: VHF Omnidirectional Range
- VOR/DME: VOR with Distance Measuring Equipment (DME)
- VORTAC: VOR with TACAN (Tactical Air Navigation, a military system)

VOR Service Volumes

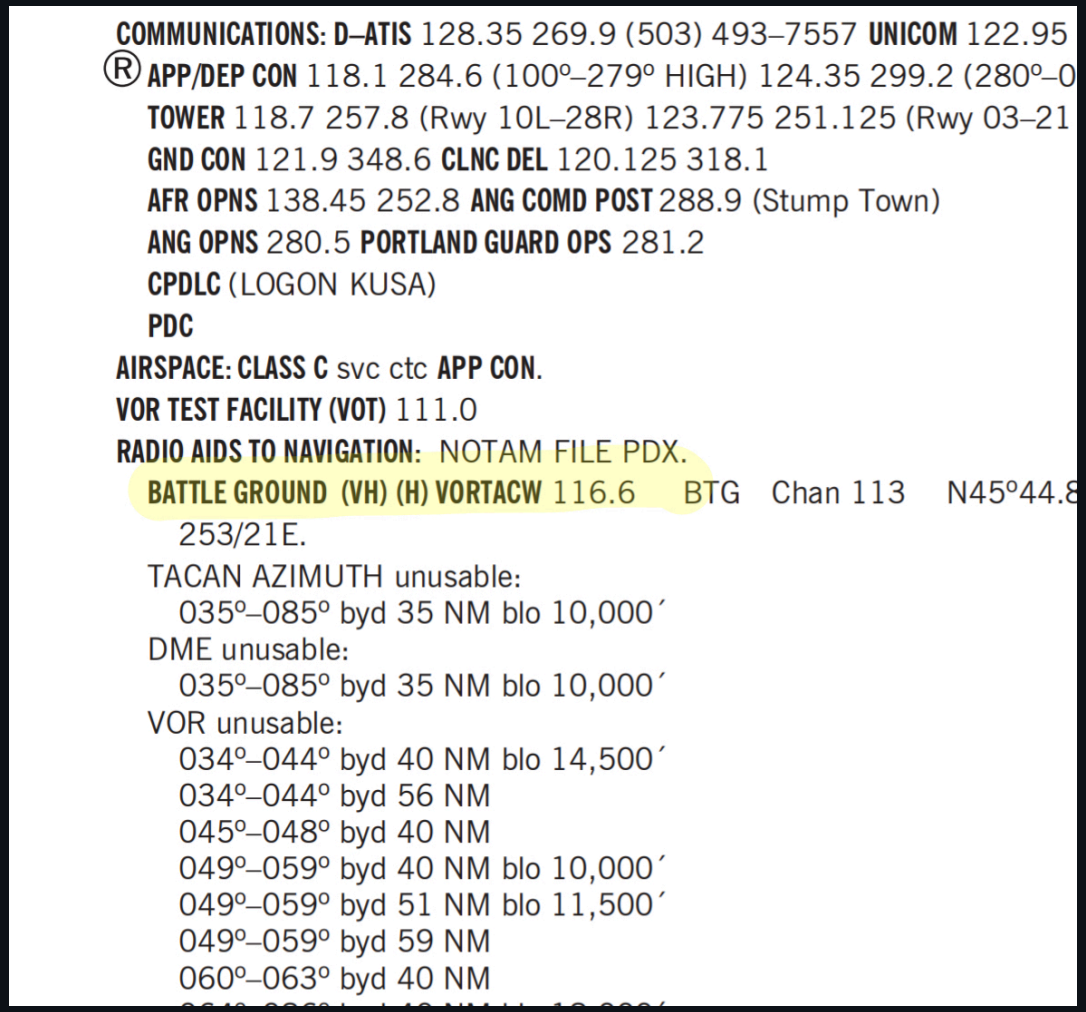
Different VORs have different power outputs.



Updated VOR Service Volumes



Service Volumes on Chart Supplement

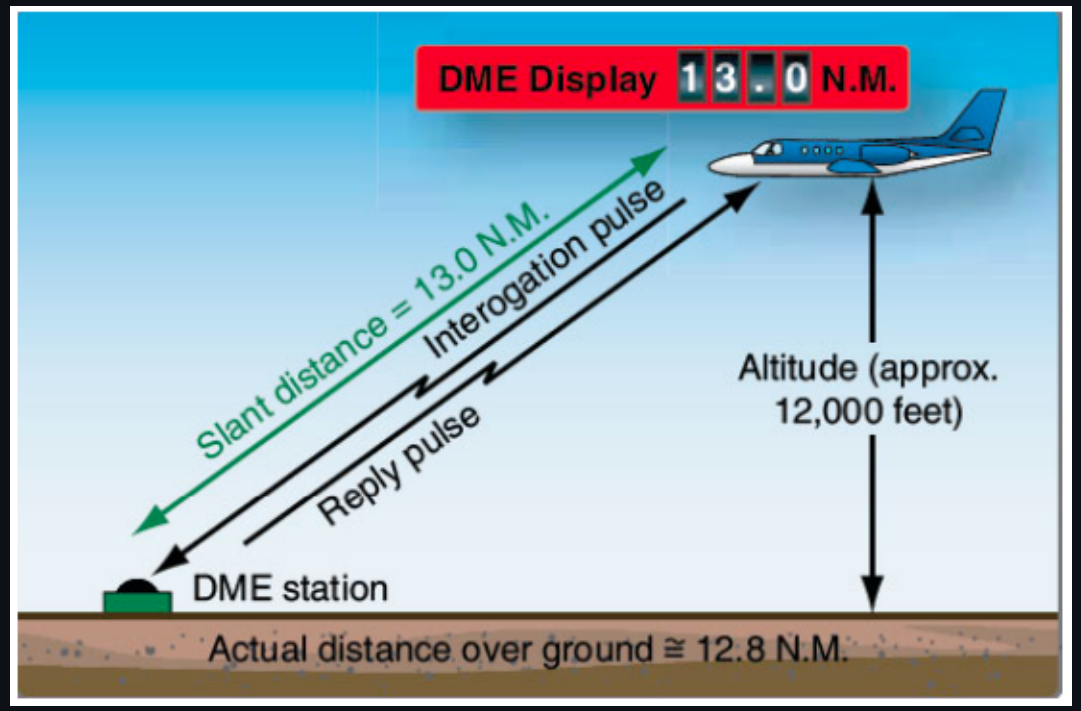


COMMUNICATIONS: D–ATIS 128.35 269.9 (503) 493–7557 **UNICOM** 122.95
Ⓡ **APP/DEP CON** 118.1 284.6 (100°–279° HIGH) 124.35 299.2 (280°–0
TOWER 118.7 257.8 (Rwy 10L–28R) 123.775 251.125 (Rwy 03–21
GND CON 121.9 348.6 **CLNC DEL** 120.125 318.1
AFR OPNS 138.45 252.8 **ANG COMD POST** 288.9 (Stump Town)
ANG OPNS 280.5 **PORTLAND GUARD OPS** 281.2
CPDLC (LOGON KUSA)
PDC
AIRSPACE: CLASS C svc ctc **APP CON.**
VOR TEST FACILITY (VOT) 111.0
RADIO AIDS TO NAVIGATION: NOTAM FILE PDX.
BATTLE GROUND (VH) (H) VORTACW 116.6 BTG Chan 113 N45°44.8
253/21E.
TACAN AZIMUTH unusable:
035°–085° byd 35 NM blo 10,000´
DME unusable:
035°–085° byd 35 NM blo 10,000´
VOR unusable:
034°–044° byd 40 NM blo 14,500´
034°–044° byd 56 NM
045°–048° byd 40 NM
049°–059° byd 40 NM blo 10,000´
049°–059° byd 51 NM blo 11,500´
049°–059° byd 59 NM
060°–063° byd 40 NM

Distance Measuring Equipment (DME)

- DME equipment on the aircraft emits a pulse, which is reflected back by the DME station
- Requires line-of-sight to the DME station
- Measures the slant distance from the aircraft to the DME

DME Slant Range



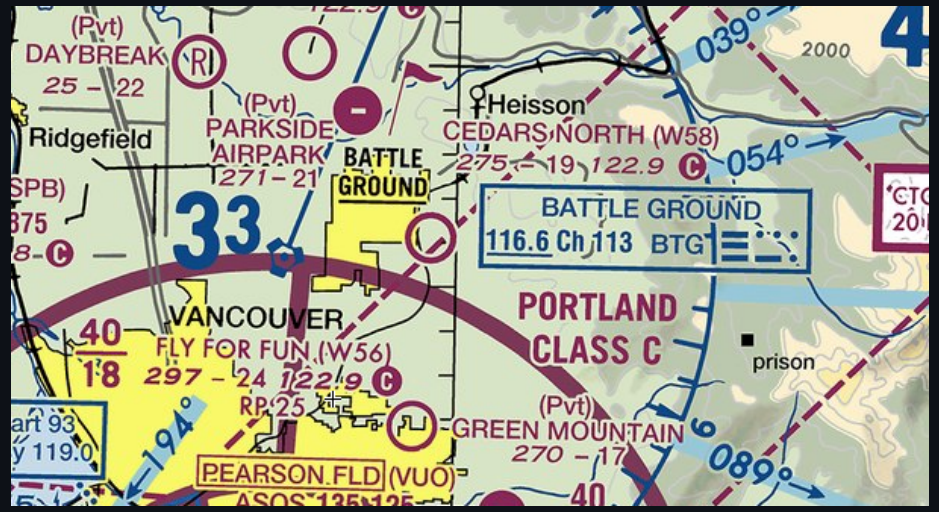
- If you were 6000' above a DME, it would show you as ~1nm away
- As long as your at least 1nm away for at least 1,000 ft., the slant error is negligible
  - Example: 8 miles from VOR at 6,000', slant range is negligible

Non-Directional Beacons (NDB)

- Aircraft equipped with ADF (Automatic Direction Finder)
- ADF receives signals from NDBs and provides a bearing pointer to the station
- No radial information

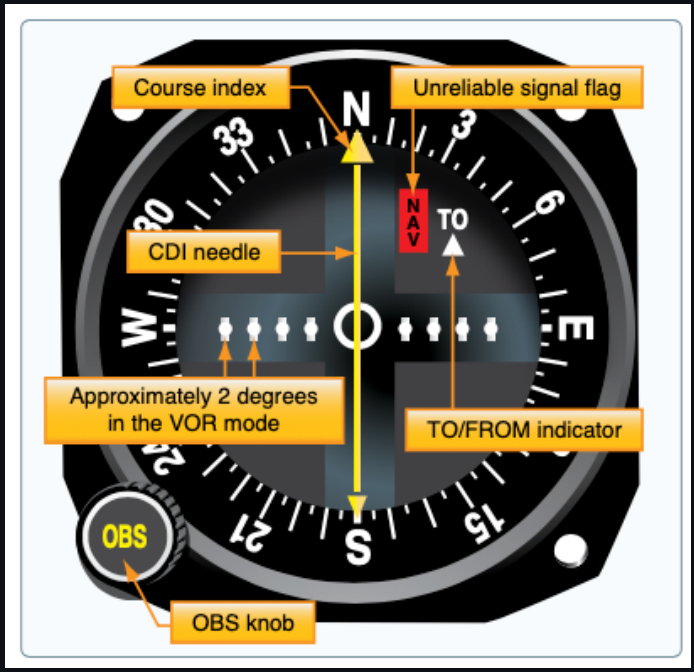
Using Radio Navigation

Tuning and Identifying Stations

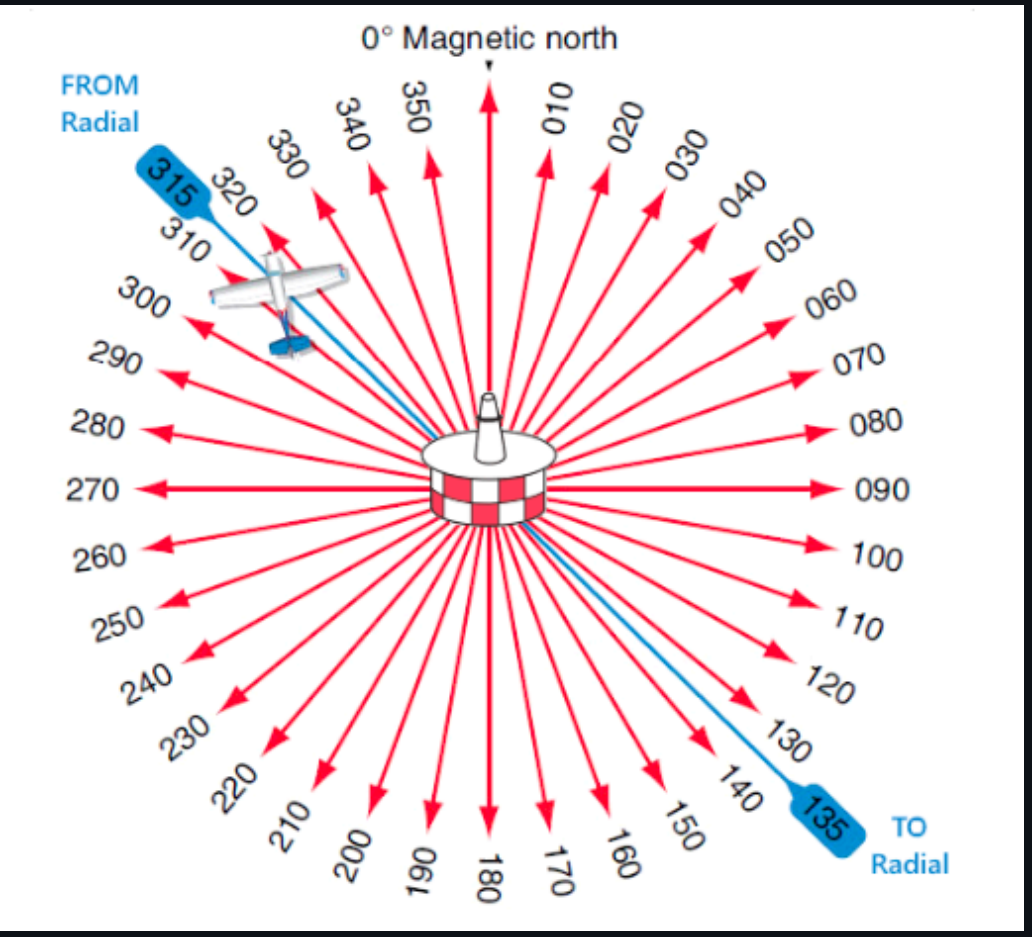


- Select VOR frequency in navigation radio
- Identify the station
  - VORs transmit a Morse code identifier on its frequency
  - Enable the NAV radio in your audio panel to listen to it
  - The absence of a code indicates the station is out of service

Reading a CDI



- Each dot represents 2° difference
- Red flag means signal unreliable
- Change selected course with OBS (omni-bearing selector knob)

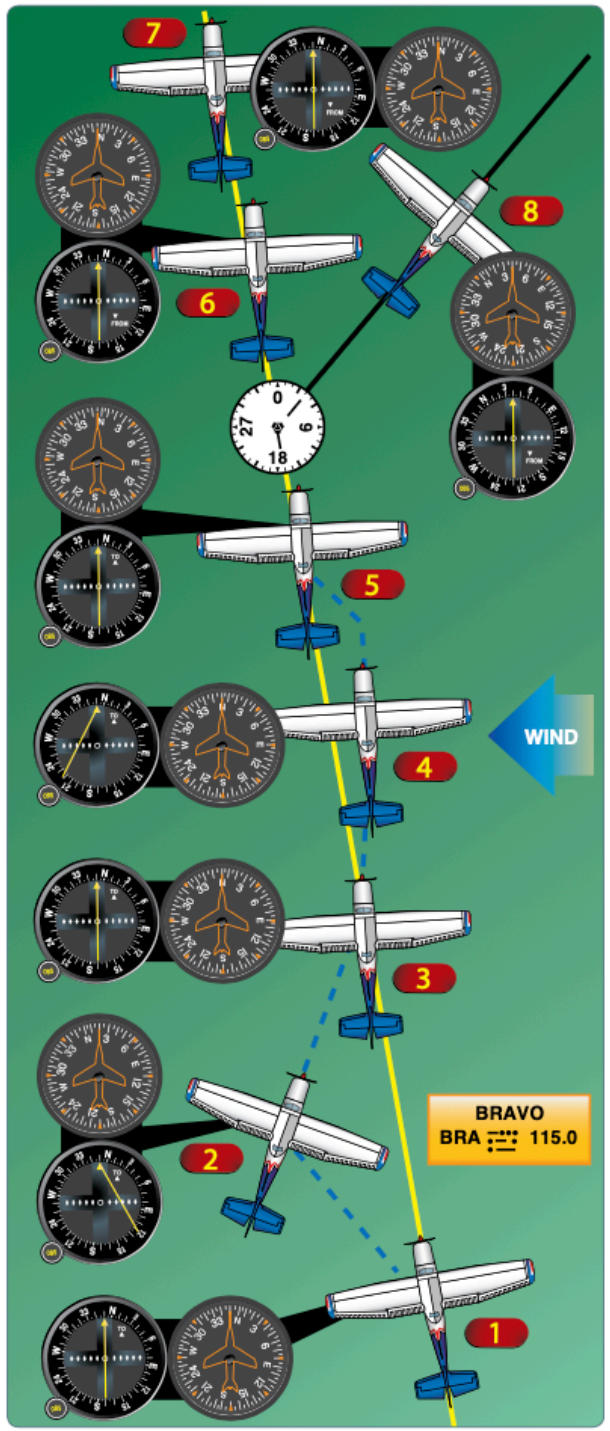


Bearing vs Radial

- Bearing is the magnetic course **TO** the station
- Radial is the magnetic course **FROM** the station

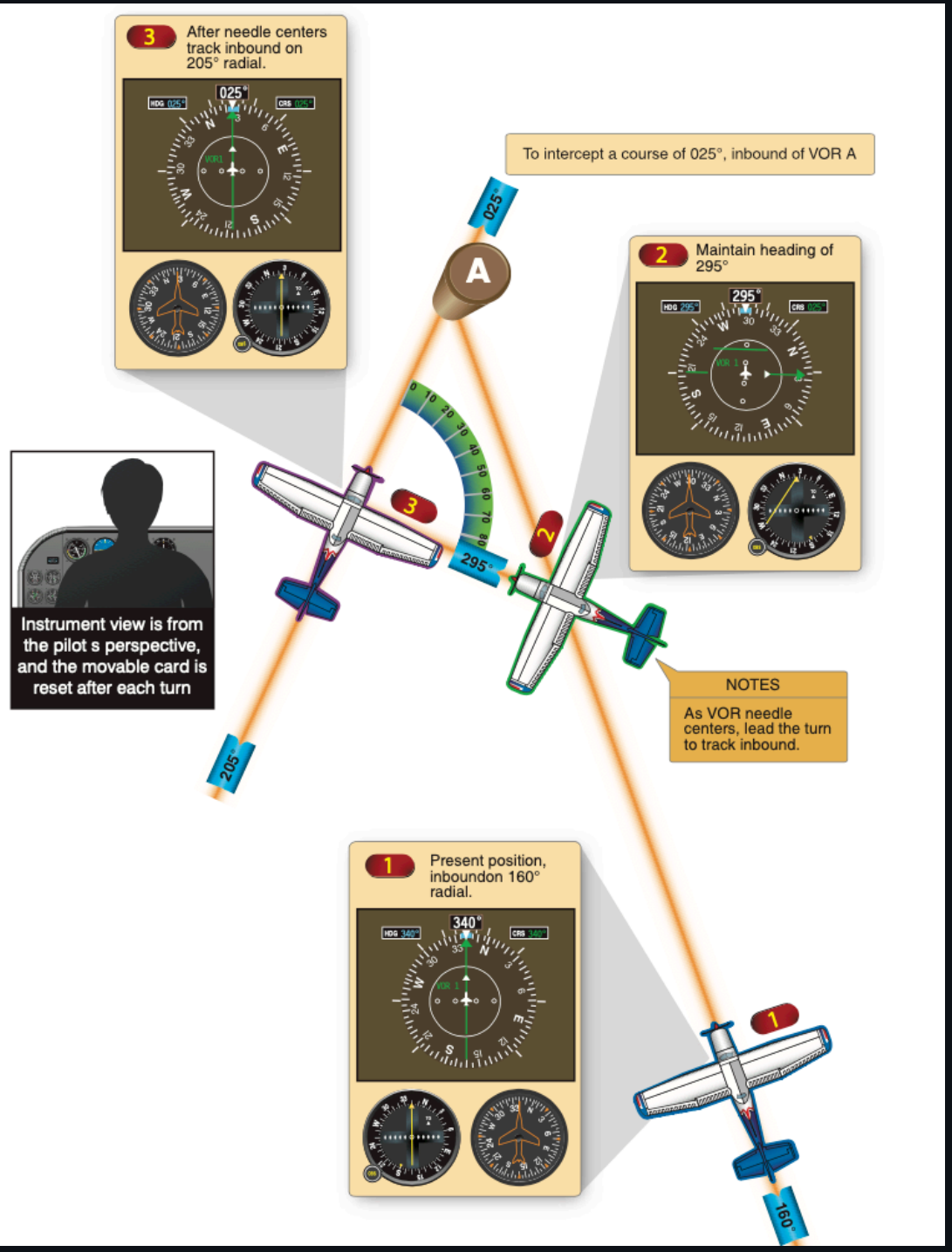
Using a VOR - Simulation

VOR simulation



Tracking a Radial

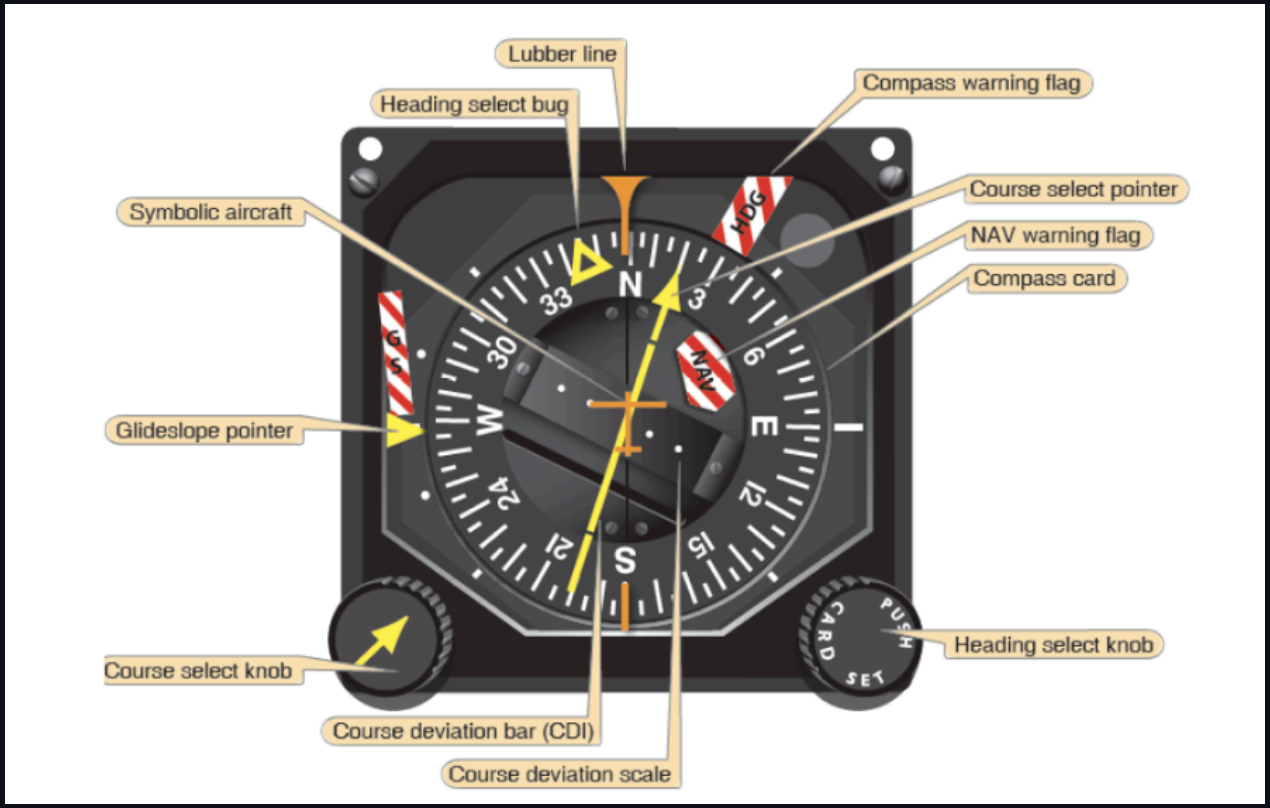
- Goal is to fly a heading so the CDI needed remains centered (with TO indication)
- Bracketing technique
  - Start with 350° (course = heading)
  - Notice the wind blows you to the left
  - Turn 10° right (360 ° heading)
  - This takes you back over the CDI radial, but the correction is too great
  - Turn 5° left (355 ° heading)
  - Make small adjustments to keep the needle centered



Intercepting a Radial

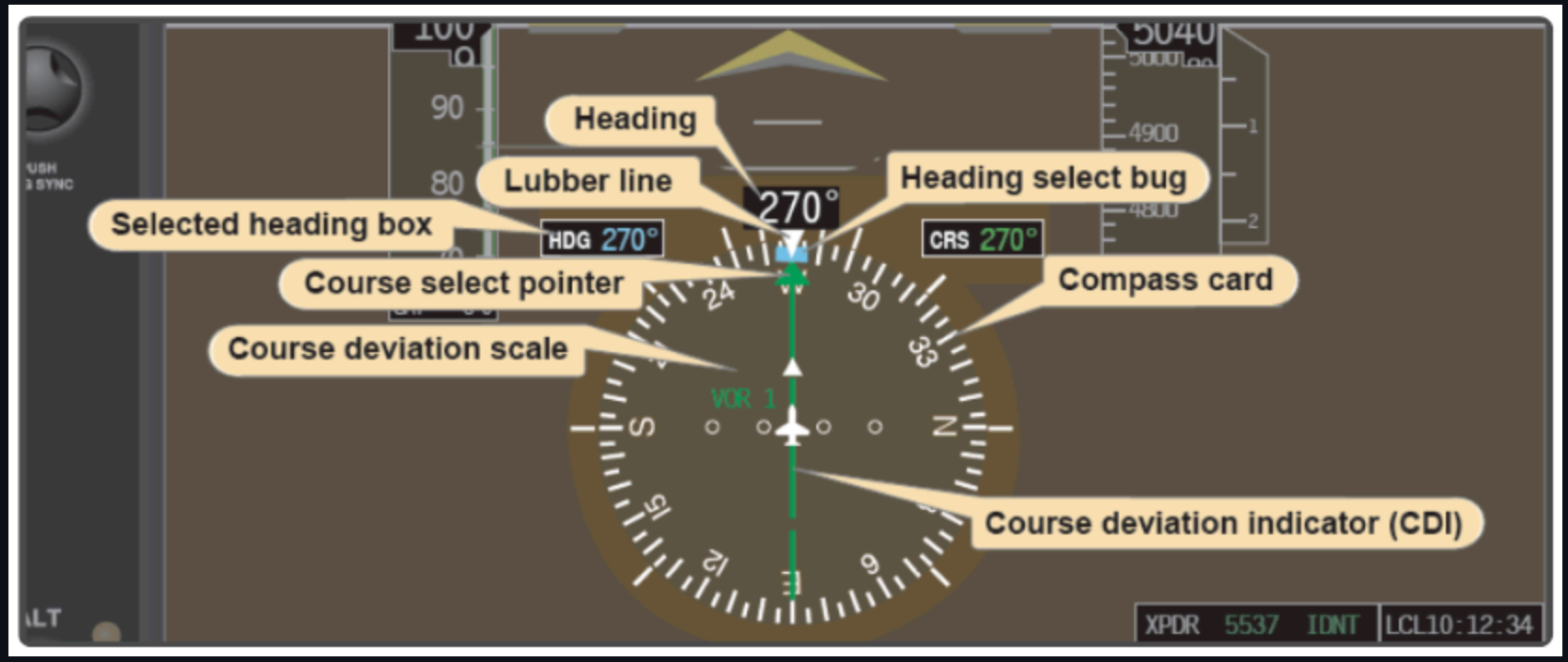
- Tune the VOR station
- Determine your current position relative to that NAVAID
- Establish an intercept angle (< 90°) and hold that heading
- As the needle centers on the new radial, turn to the new course

Horizontal Situation Indicator (HSI)



- Combination of a heading indicator and a CDI
- CDI indicator turns with the heading of the airplane

EFIS-Displayed HSI



GPS and Radar Services

Global Positioning System - GPS

- Uses a satellite array to triangulate aircraft's position on the Earth surface
  - Needs at least 4 satellites
- Used for Area Navigation: Allows point-to-point navigation without VORs
- Can be made more accurate with WAAS: Wide-Area Augmentation System
  - Uses 3 additional satellites which broadcast a correction signal

Global Positioning System - GPS (cont.)

- For IFR flights: Receiver Autonomous Integrity and Monitoring (RAIM)
  - Computes if enough satellites will be available at any given time
- Database need to updated
  - Aviation data updated every 28 days
  - Charts updated every 56 days
- GPS Outages
  - Atmospheric interference can cause outages
  - Check NOTAMs

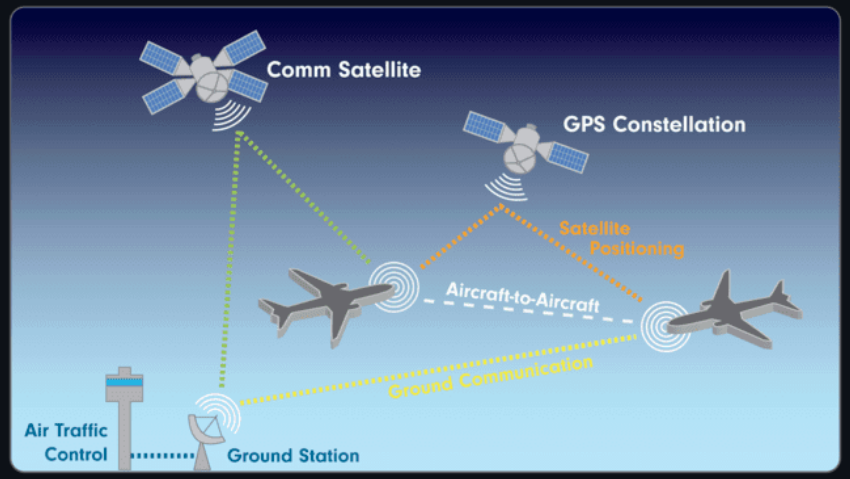
CDIs and GPS

- With GPS installed, CDI can be in GPS or VLOC (VOR or Localizer) mode
- Ensure the correct mode is selected
- In GPS mode
  - CDI has different "sensitivity"
  - Needle shows horizontal distance from desired course

Transponders

- A transponder emits a signal to a ground radar facility
- 4-digit code ("squawk code") can be entered
- Transponder modes
  - Mode A - Location and squawk code
  - Mode C - Location, squawk code, baro altitude
  - Mode S - Location, squawk code, altitude, callsign
- Emergency squawk codes
  - 7500: Hijacking
  - 7600: Loss of radio communications
  - 7700: General emergency

Automatic Dependent Surveillance - Broadcast (ADS-B)

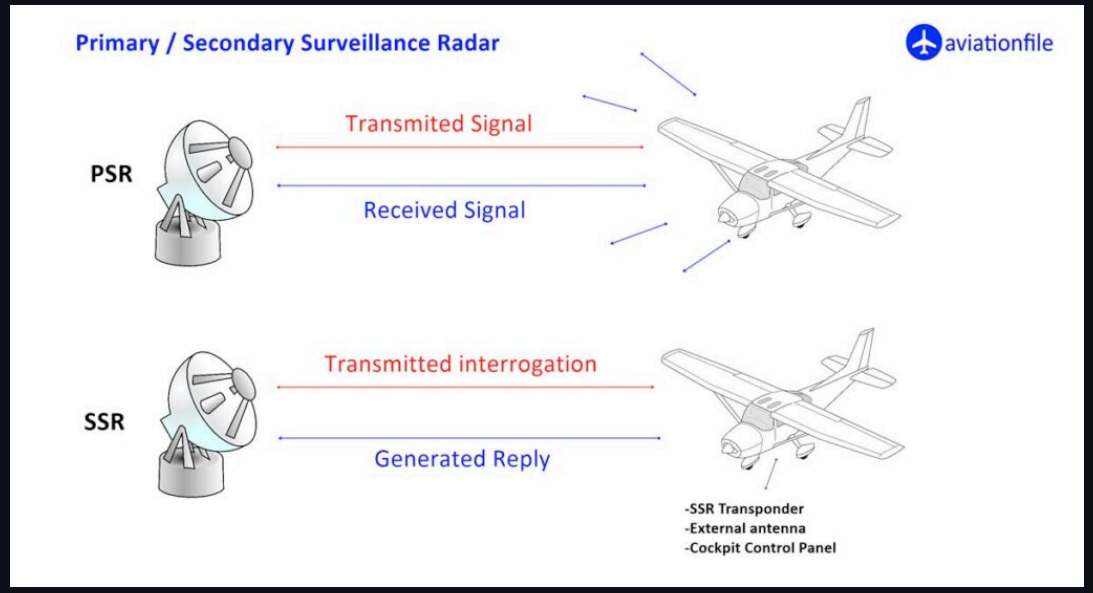


- Continual broadcast of velocity and position information
  - Requires a WAAS-based GPS position source
- Two flavors
  - ADS-B Out: Mandated in many areas since 2020
  - ADS-B In: Voluntary, traffic + weather information on cockpit displays

Electronic Flight Bags (EFBs)

- Perform flight planning, get briefings, show charts
- Keep databases up-to-date
  - Aviation data updated every 28 days
  - Charts updated every 56 days
- Beware of delays when looking at ADS-B weather information
- Bring a charger, battery pack, or backup

Air Traffic Control Radar



- ATC needs a picture of all the aircraft
- Two kinds of radar build this picture:
  - Primary radar: Radar waves bouncing off targets - position only
  - Secondary radar: Radar signal interrogating aircraft transponder - altitude, callsign

Radar Services

- VFR "flight following"
  - Traffic advisories
  - Airspace alerts
  - Advisory altitudes and headings
- See and avoid still applies
- You must maintain VFR and required cloud clearance
- You need to maintain a safe altitude

Flight Following Radio Calls

- "Portland Approach, Cessna 12382, with a request"
- "Portland Approach, Cessna 12382, 3 miles north of the Salem airport, 3000 feet, VFR to to KBFI, request flight following."
- "Cessna 12382, Portland Approach, radar contact 3 miles north of Salem airport, squawk 4583."

Summary

- VORs: Radial or bearing to/from station
- DME: Measure slant distance
- NDB: Gives you direction to the station
- Using VORs
  - Tune and ID the station with morse code
  - CDIs and HSI
  - Intercept and tracking a course
- Transponders: Give altitude and ID information
- ADS-B Out: Continual broadcast of position/velocity
- GPS: Satellite-based navigation
- EFB: Keep them charged and updated
- Radar Services: VFR flight following

Knowledge Check

You tune a VOR and ID the station, only to find there's no morse code being transmitted on the station's frequency.

What does this mean? What would you use instead?

Knowledge Check

The Olympia airport (KOLM) has a High power VOR that you plan to use in your flight plan. Your planning to cruise at 4500'.

Will you be able to reliably use the VOR signal from 100nm away? What about 50nm?

Knowledge Check

You're using VFR flight following, and they asked you to climb to 4500' for traffic. The cloud bases are around 4000'.

What would you do?