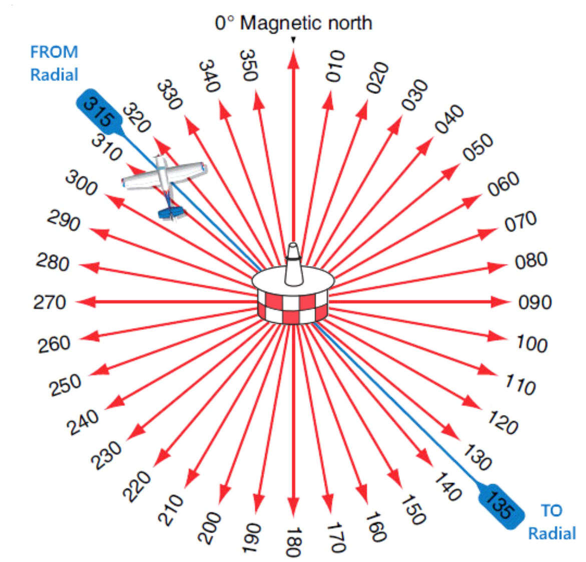
Navigation Systems and Radar Services

Objective

To ensure the applicant learns about ATC Radar Services and the types of navigation systems found in general aviation airplanes, as well as their usage.

Purpose

With the broad availability of GPS, getting lost is fortunately no longer a common occurrence for pilots, however pilots cannot rely on GPS in many cases. This lesson introduces pilots to ATC Radar Services and their use, as well as the types of radio aids to navigation available to VFR pilots which can be used to supplement basic pilotage, dead reckoning, and GPS usage.



Schedule

- **Ground Lesson**: 30 minutes
- **Student Q&A**: 10 minutes

Equipment

- Whiteboard / Markers (optional)
- Model Airplane (optional)

Student Actions

- Ask any questions, receive study material for the next lesson.
- Watch linked video.
- Listen to linked podcast episode.
- Review listed references.

Instructor Actions

- Deliver the ground lesson (below).
- Answer student questions.

Completion Standards

- Student can explain the following concepts:
  - VORs - Concept of Operation, Type of Antenna Used, and their use, including:
    - Tuning and Station Identification, CDI and TO/FROM flag indications
  - DME - Concept of Operation, Type of Antenna Used, and its use, including:
    - Tuning, Slant Range
  - GPS - Concept of Operation, Type of Antenna Used, and its use, including:
    - Number of satellites required, the purpose of RAIM and WAAS, CDI indications and sensitivity

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Editable versions available at binnsflightservices.com/cfibinder

References

- Captain Joe - “WHAT is a VOR? Explained by CAPTAIN JOE”
    - YouTube - https://www.youtube.com/watch?v=wuLTppemEgA
- Opposing Bases: Air Traffic Talk Podcast - Episode OB006: VFR Flights Matter
    - http://opposingbases.libsyn.com/ob006-vfr-flights-matter
- FAA-H-8083-25C (Pilot’s Handbook of Aeronautical Knowledge) - Chapter 16, Page 22-34 [Ground-Based Navigation]
- AIM-2024-03-21 (Aeronautical Information Manual) - Chapter 1 [Air Navigation]
- FAA-S-ACS-6C (Private Pilot ACS) - Area VI Task B
- FAA-S-ACS-7B (Commercial Pilot ACS) - Area VI Task B
- FAA-S-ACS-25 (CFI ACS) - Area II Task H

Ground Lesson Outline

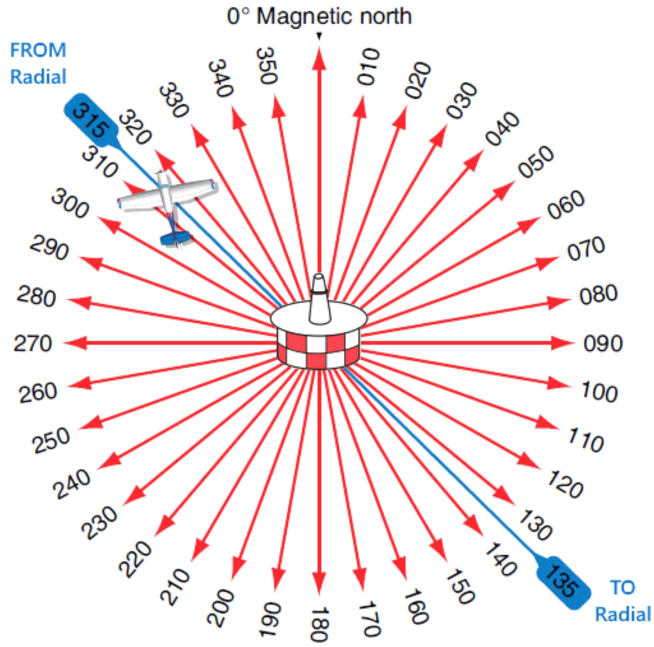
- VHF Omnidirectional Range (VOR)
    - Concept of Operation - 360 ‘radials’ extending from the station, pilots track these courses
        - Service Volumes
    - Antenna - Usually two ‘whiskers’ on the vertical tail
    - Usage - Tuning, Station Identification, CDI, TO/FROM Indication
- Distance Measuring Equipment (DME)
    - Concept of Operation - Interrogation and response, timed according to the speed of light
    - Antenna - Small ‘fin’ antenna on the belly of an airplane
    - Usage - Tuning, Distance Display, Slant Range
- Global Positioning System (GPS)
    - Concept of Operation - Time-of-Flight calculations based on an orbiting network of satellites
        - Relies on satellites being in view (over the visible horizon)
        - 4 Satellites = 3D Position, 5 Satellites = RAIM, 6 Satellites = Fault Detection and Exclusion
        - WAAS - 3 ‘correction’ signal satellites in geostationary orbit
    - Antenna - Round ‘puck’-like disc on top of airplane
    - Usage - Waypoints, CDI, CDI Sensitivity, RAIM Prediction/WAAS
- ATC Radar Services
    - Flight Following
        - How to Request
        - Pilot Responsibilities
    - Limitations of ATC Radar - Heading vs. Track, Can’t See Clouds, Weather
- Transponders - Mode A/C/S, Ident
    - ADS-B Out Requirements

Common Errors

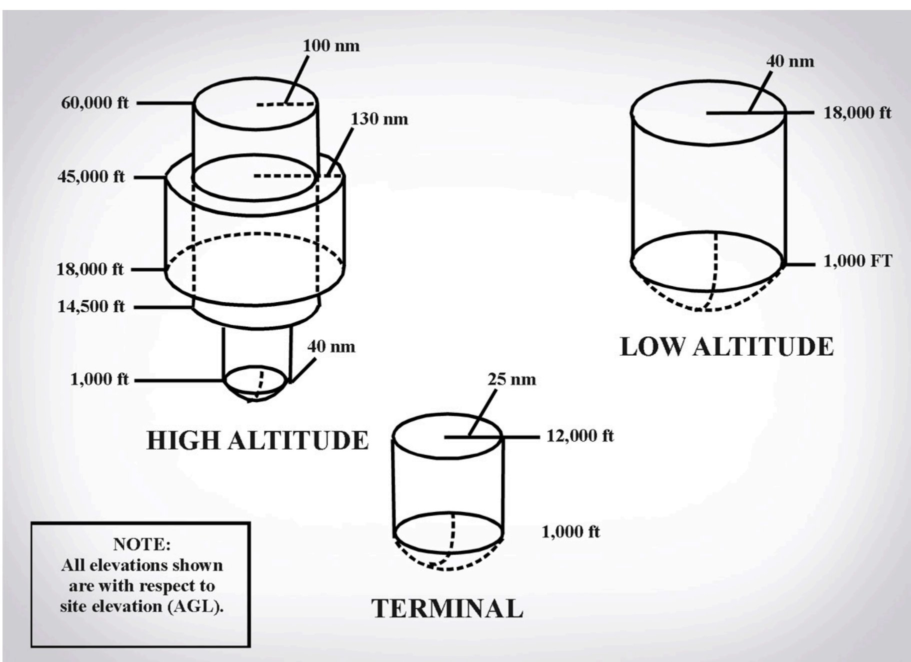
- Misunderstanding the VOR TO/FROM indication.

Ground Lesson Content

- **VHF Omnidirectional Range (VOR)**
  - **Concept of Operation** - A VHF radio station broadcasting two signals on 108.00 to 117.95 MHz, creating 360 'radials' extending from the station. Radials are determined by comparing the phase of a rotating signal (30 times per second) to a fixed reference signal. Pilots can determine which 'radial' they are on, and track these courses to and from VOR stations.

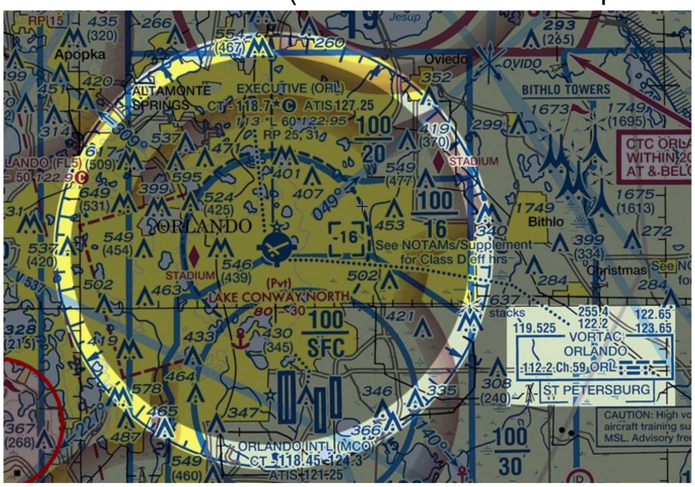


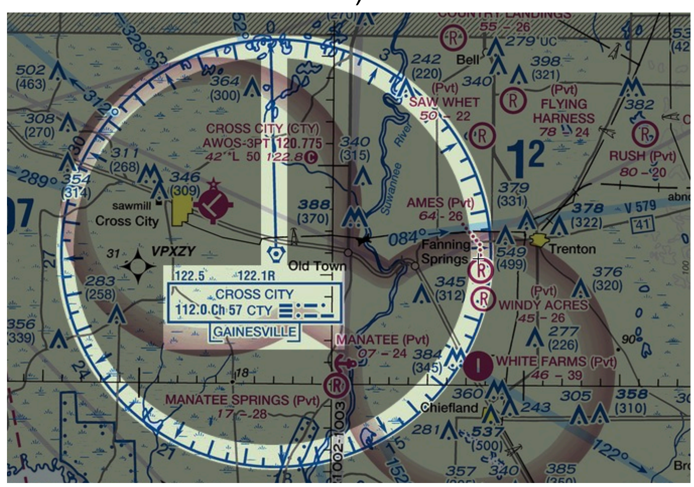
    - **Service Volumes** - VORs, as VHF radio signals, rely on line-of-sight transmission. Different VORs have different *service volumes*, which define the areas where the VOR signal is usable for navigation. **In general, below 1,000 feet AGL, VOR signals are unreliable.**



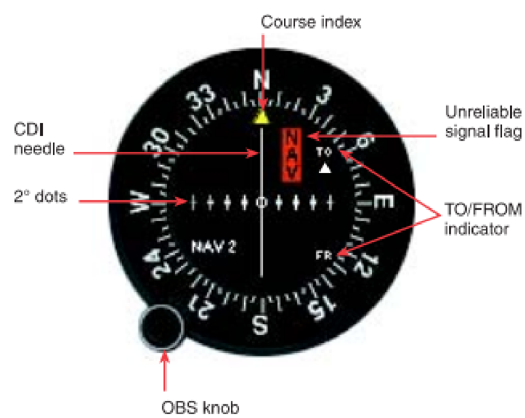
- **Antenna -** Usually two 'whiskers' on the vertical tail. Also shared with the ILS (Localizer) receiver, if equipped.

- **Usage -**
    - **Station Identification -** Before using a VOR, pilots must tune it into the VOR receiver, which is often the same as the normal VHF Com radio. After tuning it, VOR stations **must** be identified by listening to the morse code identifier broadcast by the stations. (See the morse code depicted on the VFR sectional charts)



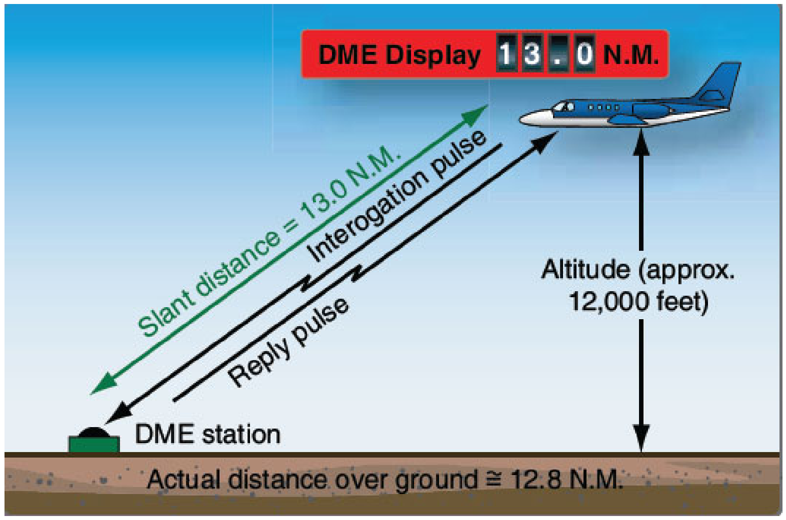


    - **CDI, TO/FROM Indication -** Whenever an airplane is *on a radial*, the *Course Deviation Indicator* (CDI) will display a **FROM** indication. For example, an airplane is due north of a station, the CDI will indicate a FROM flag on the 360 degree radial. Pilots often want to fly *to* a VOR station. In these cases, they tune the *reciprocal* (180 degrees offset) radial from the one they are currently on. For example, an airplane to the north of a station wanting to fly to the station and fly south (180 degrees), should set the 180 degree radial using the *Omni-Bearing Selector* (OBS) knob, and look for a TO flag.

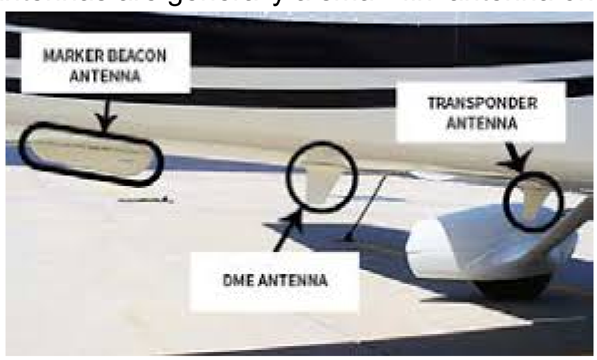


        - When the pilot is on course, the CDI needle will be centered.
        - **Heading Towards the Station (TO Flag)/Heading Away From the Station (FROM Flag) -** When the pilot should fly left to intercept the course, the CDI needle will deflect left. The needle will deflect right for right corrections.
        - **Heading Towards the Station (FROM Flag)/Heading Away From the Station (TO Flag) -** *The CDI needle indication will be reversed!*

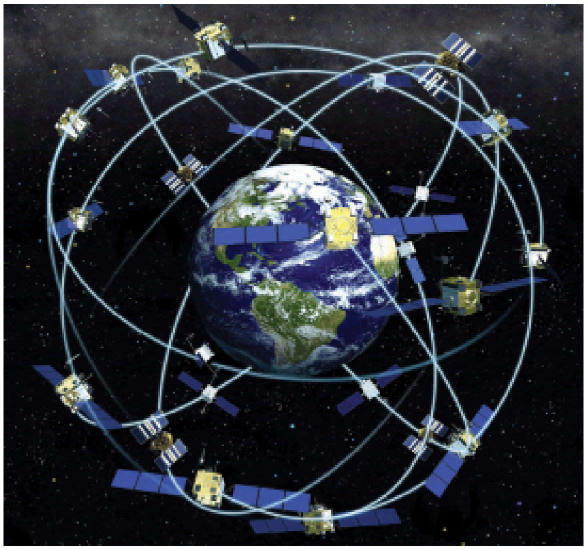
- **Distance Measuring Equipment (DME)**
    - **Concept of Operation** - DME radios operate on the principle that the speed of light is a fixed number. DME radios send an interrogation pulse and wait for a reply pulse, and the timing of these signals can be compared using the speed of light to estimate distance.

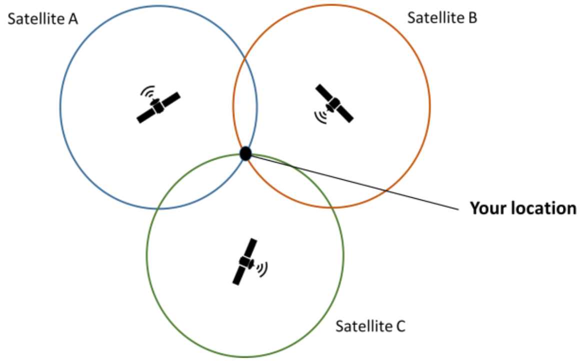


    - **Antenna** - DME antennas are generally a small ‘fin’ antenna on the belly of an airplane.



    - **Usage** - Pilots only generally need to specifically tune a DME if it is a separate radio than the VOR receiver. DME operates on a different frequency range than VOR, but pilots tune the VOR station frequency into the DME receiver and the proper DME frequency is calculated by the receiver.
        - The DME radio produces only a distance display, which is the number of nautical miles to the station. Note that this distance is *slant range*, which is the direct line-of-sight distance to the station. **At high altitudes, this can be quite different than the distance along the ground!**
- **Global Positioning System (GPS)**
    - **Concept of Operation** - Time-of-Flight calculations based on an orbiting network of satellites
        - Relies on satellites being in view (over the visible horizon)
        - 4 Satellites = 3D Position, 5 Satellites = RAIM, 6 Satellites = Fault Detection and Exclusion
        - **WAAS** - 3 ‘correction’ signal satellites in geostationary orbit





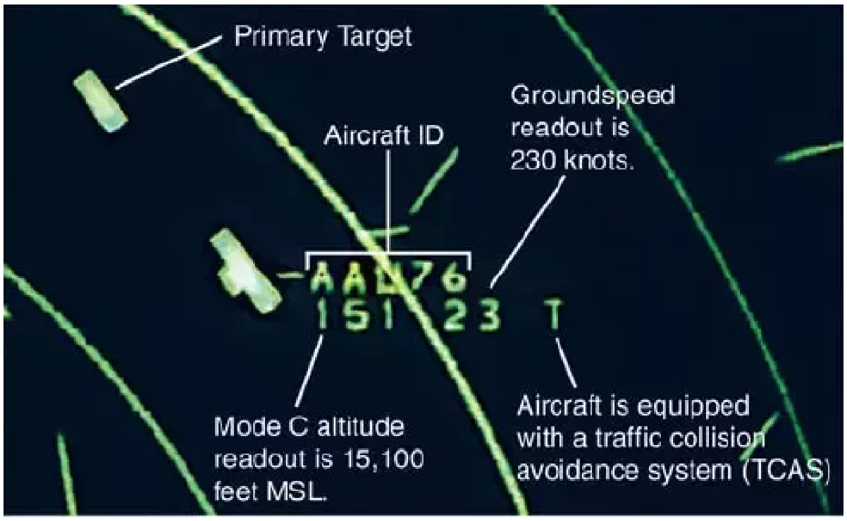
- **Antenna -** Round 'puck'-like disc on top of airplane.

- **Usage -**
  - **Waypoints -** GPS receivers generally rely on pilots to create flight plans, which are sequences of named, pre-programmed locations. The *course* created between each waypoint is depicted on a screen, usually as a magenta line.
  - **CDI -** GPS receivers display the airplane position on a moving map, but most also support the CDI needle, similar to a VOR receiver. The CDI indicates the direction pilots should fly to return to the course line, which is usually the next waypoint in the GPS.
  - **CDI Sensitivity -** Unlike VOR CDIs, where the amount of needle deflection varies with the distance from the station, GPS CDIs vary a fixed amount, depending on the distance from the course line. (Called the *cross-track distance*) The sensitivity (amount of cross-track distance per 'dot' of CDI deflection) depends on the phase of flight, with Enroute (Cruise) being the least sensitive.
  - **RAIM Prediction/WAAS -** In order to ensure the reliability of the GPS signal, there are multiple tools built into modern GPS receivers to ensure that satellite coverage is sufficient. If the GPS is not equipped for the Wide-Area Augmentation System (WAAS), there is a tool called the RAIM Prediction Tool, which can compute whether at least 5 satellites will remain visible during the entire flight. If the GPS is equipped with WAAS, this is generally not necessary.

- **ATC Radar Services**
  - **Flight Following -** Commonly used by VFR pilots, officially called *Radar Services*, flight

following is available to pilots from most ATC radar facilities. Pilots generally request flight following, and inform ATC of their type of aircraft, route of flight, intended altitude and other important information, etc. ATC then provides traffic advisories, occasionally weather advisories, and helps to coordinate with upcoming ATC facilities.

    - **How to Request** - Requesting flight following is simple:
        - **Example:** "Orlando Approach, Cessna N12345, 5 miles south of Leesburg, VFR to Orlando Executive at 3,000 feet, requesting Flight Following"
        - **Example Reply:** "Cessna N12345, Orlando Approach, Squawk 1234, Maintain VFR at 3,000 feet on course"
    - **Pilot Responsibilities** - When receiving flight following, pilots are expected to inform ATC of any altitude, speed, or large heading changes. Additionally, **pilots must maintain VFR cloud clearances and inform ATC if a climb, descent, or turn is required to maintain VFR!**



  - **Limitations of ATC Radar** - ATC radar is generally designed to depict airplanes, and has very limited weather display capabilities.
    - **Heading vs Track** - ATC radar sees only an airplanes *ground track*, not it's heading! However ATC will issue headings. Even if a pilot is able to determine their actual ground track (i.e. using a GPS), pilots should fly the *headings* given by ATC, and not attempt to match the ground track!
    - **Clouds are Invisible** - ATC does not know where the clouds are! If a pilot sees that they cannot maintain VFR cloud clearances, they must inform ATC!
    - **Weather Capabilities** - ATC radar only displays precipitation (rain, snow, etc), which does not account for all types of hazardous weather. **While ATC advisories on weather can be helpful, they should not be relied upon!**
- **Transponders** - ATC Radar sees aircraft by 'interrogating', that is, sending a request and receiving a reply, from transponders on aircraft. Transponders send back with them, among other data, a *squawk code*, which is an octal identifier between 0000 and 7777. Transponders can operate in several modes, but the most common are:
  - **Mode A** - Squawk code only.
  - **Mode C** - Squawk code and altitude reporting.
  - **Mode S** - Squawk code, altitude reporting, and a hexadecimal code which represents the aircraft registration number. E.g. N12345 = A061D9
  - Transponders are also capable of sending an "*Ident*", which is triggered by the pilot at the request of ATC. When pilots trigger the Ident function, the target will change slightly on the ATC radar display, to aid in target identification.

- **ADS-B Required Airspace**