06-06-2025 - RNav Lecture 1

> Date & Time: 2025-06-06 17:55:02
> Location: [Insert Location]
> [Insert Title]
> `VDF and Radar Navigation` `QDM/QDR Bearings` `ADS-B and Transponder Codes`

Theme

This lecture provides a comprehensive overview of aviation navigation principles, focusing on ground direction finding, VDF, QDM/QDR bearings, radar operation, and the use of transponders and ADS-B. It covers theoretical formulas, practical examples, error sources, and the impact of weather and terrain on navigation systems. The session also addresses the interpretation of navigation instruments and emergency transponder codes, essential for safe and effective flight operations.

Takeaways

1. Principle of ground direction finding
2. Role of ATC and VDF in navigation
3. QDM and QDR definitions and usage
4. Relationship between QDM, QDR, and radials
5. Formula for theoretical VHF radio range
6. Impact of antenna and aircraft altitude on range
7. Classification of VDF accuracy (Class A, B, C, D)
8. Radar principles and operation
9. Calculation of distance using radar
10. Primary and secondary surveillance radar

Highlights

- `"If you change the altitude, it changes also? No. Of course, if I want to catch the signal, I have to climb higher."-- Speaker 1`
- `"The automatic broadcast of the aircraft's position depends on the aircraft's position having on board Global Navigation System, GNSS capability."-- Speaker 1`

- `"Magnetic bearing equals magnetic heading plus relative bearing."-- Speaker 1`
- `"Never imagine it in your head. Always draw."-- Speaker 1`

Chapters & Topics

Principle of Ground Direction Finding

> Ground direction finding is based on the principle that a radio receiver can take a bearing on a radio transmission and determine its direction in relation to the receiving radio. This is used in aviation to determine the direction to or from a radio navigation station (such as VOR or NDB) from the aircraft.

- **Keypoints**
  - Aircraft tunes into the frequency of a ground station (e.g., NDB, VOR).
  - Both aircraft and ATC can determine the direction between the aircraft and the station.
  - ATC can provide pilots with the specific magnetic bearing to fly to reach a station.
- **Explanation**
  When a pilot requests direction to a specific station, ATC uses VDF (Very High Frequency Direction Finding) to provide the magnetic bearing in degrees. The information can be displayed as a trace or digitally on ATC systems. Modern systems allow controllers to select aircraft and stations on a screen to automatically display the direction.
- **Considerations**
- Pilots need to request direction using proper phraseology (e.g., ‘requesting direction to BURGOS VOR’).
- Understanding the difference between magnetic and true bearings is essential.

QDM and QDR Definitions and Usage

> QDM is the magnetic bearing **to**the station, while QDR is the magnetic bearing **from**the station. These are essential for navigation and are often tested in exams.

- **Keypoints**

  - QDM: Magnetic bearing to the VDF station (e.g., VOR).
  - QDR: Magnetic bearing from the VDF station.
  - QDR always equals the radial.

- QDM and QDR are related by 180 degrees (QDM = QDR ± 180, adjust for values over 360).
- Need to know also QUJ & QTE.
  - QUJ=Aircraft True Track **to**VOR Beacon
  - QTE: Aircraft True Track **from**VOR Beacon

- **Explanation**
  To find the direction to a station, pilots request QDM from ATC. For example, if QDM is 045, QDR is 225 (045 + 180). The radial is the same as QDR. If the aircraft is on radial 225, QDR is 225, and QDM is 045. The formula QDM = QDR ± 180 is used, and if the result exceeds 360, subtract 360.

- **Examples**

  > If the aircraft's QDM is 045, then QDR is 225 (045 + 180). If the aircraft is on radial 135, QDM is 315 (opposite direction), and QDR is 135.

  - Identify the QDM (direction to the station).
  - Add 180 to get QDR (direction from the station).
  - If the sum exceeds 360, subtract 360 to get the correct bearing.

- **Considerations**

- Always use magnetic bearings for QDM and QDR.

- Remember the relationship between QDM, QDR, and radials for exam purposes.

- **Special Circumstances**

- If the calculated bearing exceeds 360 degrees, subtract 360 to obtain the correct value.

Formula for Theoretical VHF Radio Range

> The theoretical range for VHF radio communication depends on the height of the transmitting antenna and the altitude of the aircraft. The formula is: Range (nautical miles) = 1.23 × (√transmitter height in feet + √receiver height in feet).

- **Keypoints**
  - Range is always given in nautical miles.
  - Formula: Range = 1.23 × (√transmitter height + √receiver height).
  - Higher aircraft altitude increases the range.
  - Lower antenna height reduces the range.
- **Explanation**
  For example, with an aircraft at 2,500 feet and an antenna at 25 feet, the range is

calculated as 1.23 × (√2500 + √25) = 1.23 × (50 + 5) = 1.23 × 55 = 67.65 nautical miles. If the aircraft is at 70 nautical miles, it will not receive the signal. Increasing altitude increases the range.

- **Examples**
  > Aircraft at 2,500 feet, antenna at 25 feet. Theoretical range = 1.23 × (√2500 + √25) = 67.65 nautical miles.

  - Calculate the square root of the aircraft altitude (√2500 = 50).
  - Calculate the square root of the antenna height (√25 = 5).
  - Add the two results (50 + 5 = 55).
  - Multiply by 1.23 (1.23 × 55 = 67.65).
- **Considerations**
- If signal is weak or lost, climbing to a higher altitude may restore communication.
- Remember the formula for exam purposes.
- **Special Circumstances**
- If experiencing static or poor ATC communication, climb to a higher altitude to improve signal reception.

Classification of VDF Accuracy

> VDF (Very High Frequency Direction Finding) station accuracy is classified into four classes: Class A (±2 degrees), Class B (±5 degrees), Class G (±10 degrees), and Class D (worse than G).

- **Keypoints**
  - Class A: ±2 degrees accuracy.
  - Class B: ±5 degrees accuracy.
  - Class G: ±10 degrees accuracy.
  - Class D: worse than G (exact value not specified).
- **Explanation**
  When receiving QDM from a station, there may be an error. If the error is within ±2 degrees, the station is Class A. Other classes have larger permissible errors.
- **Considerations**
- Know the accuracy classes and their degree values for exams.

Radar Principles and Operation

> Radar operates by transmitting a beam of radio pulses (in UHF, SHF, or EHS frequencies). When these pulses hit an object (such as an aircraft), they are reflected (echoed) back to the radar receiver. The time taken for the pulse to travel to the object and back is used to calculate the distance.

- **Keypoints**
  - Radar transmits pulses at the speed of light (300,000 kilometers per second).
  - Distance is calculated as: Distance = (Speed × Time) / 2.
  - If an echo is received in 1/1000 of a second, the total distance traveled is 300 kilometers (out and back), so the object is 150 kilometers away.
  - Radar may not detect objects close to the horizon due to terrain masking.
- **Explanation**
  The radar sends out a pulse. When the pulse hits an aircraft, it is reflected back. The radar measures the time taken for the pulse to return. Since the pulse travels to the object and back, the actual distance is half the total distance traveled by the pulse.
- **Examples**
  > If an echo is received back in 1/1000 of a second, the pulse has traveled 300 kilometers. The distance to the object is 150 kilometers.

  - Speed of radio wave = 300,000 kilometers per second.
  - Time = 1/1000 second.
  - Total distance = 300,000 × 1/1000 = 300 kilometers.
  - Distance to object = 300 / 2 = 150 kilometers.
- **Considerations**
- Radar may not detect low-flying objects due to terrain or obstacles.
- Military aircraft may fly at low altitude to avoid radar detection.
- **Special Circumstances**
- If an object is close to the horizon, radar may not detect it due to terrain masking.

Primary and Secondary Surveillance Radar

> Primary Surveillance Radar (PSR) uses a rotating parabolic antenna to detect objects by their reflected radio pulses. It only shows that an object is present but does not provide identification. Secondary Surveillance Radar (SSR) is more sophisticated and can provide additional information such as aircraft identity.

- **Keypoints**
  - Primary Surveillance Radar detects presence of objects but not their identity.
  - Secondary Surveillance Radar can provide call sign and other information.
  - Primary Surveillance Radar is considered an older technology.
- **Explanation**
  PSR works by detecting the echo from objects. It cannot identify the aircraft, only that something is present. SSR requires additional equipment (such as a transponder) on the aircraft to provide identification.
- **Considerations**
- Understand the limitations of PSR for identification.

- SSR requires aircraft to have compatible equipment.

Plant Position Indicator (PPI) and Radar Display

> The Plant Position Indicator (PPI) is a circular radar display where the radar antenna is represented at the center. As the antenna rotates, a trace rotates around the center, and echoes from objects appear as bright spots that fade until re-illuminated on the next sweep.

- **Keypoints**
  - PPI is a circular layout with the radar antenna at the center.
  - The trace rotates at the same speed as the radar.
  - Echoes from objects appear as bright plots and fade after the trace passes.
  - Controllers historically used rulers to measure distance from the airport to objects.
- **Explanation**
  The PPI allows controllers to visually identify the position and movement of objects relative to the radar antenna. The trace's rotation and the fading of echoes help in distinguishing moving and stationary objects.
- **Considerations**
- Controllers must understand how to interpret the fading and re-illumination of echoes.
- Measurement of distance requires understanding of the PPI layout.
- **Special Circumstances**
- If the trace does not rotate or the display malfunctions, controllers may lose situational awareness and should switch to backup systems.

Radar Range, Accuracy, and Influencing Factors

> Radar range and accuracy depend on frequency band, line-of-sight, power, target characteristics, and environmental factors such as terrain and weather.

- **Keypoints**
  - Radar operates in VHF, SHF, EHF, and UHF bands.
  - Objects below the radar horizon or shielded by terrain are not detected.
  - Terrain can cause clutter, leading to permanent areas of false echoes.
  - Radar range decreases if power is too high.
  - Material and size of the target affect the strength of the radar return.
- **Explanation**
  Controllers must consider the radar's frequency, power settings, and environmental conditions when interpreting radar data. Metallic and large objects provide stronger returns, while stealth or composite materials may be harder to detect.

- **Examples**
  > A Cessna 172, being a metallic and non-stealth aircraft, is easily detected by radar, while an F-117 Nighthawk, designed for stealth, is difficult to detect.

  - Radar returns are stronger from metallic, non-stealth aircraft.
  - Stealth technology reduces radar cross-section, making detection challenging.
- **Considerations**
- Controllers should be aware of clutter and filter settings.
- Weather and terrain can significantly impact radar performance.
- **Special Circumstances**
- If intense precipitation occurs, radar displays may be cluttered; use modern filters to remove unnecessary returns.

Primary vs. Secondary Surveillance Radar (SSR)

> Primary radar detects objects by reflected radio waves, while SSR augments this by interrogating aircraft transponders for additional data such as squawk code and altitude.

- **Keypoints**
  - SSR provides ATC with flight parameters beyond location.
  - SSR uses coded interrogation at 1030 MHz and receives replies at 1090 MHz.
  - SSR enables identification of aircraft via transponder codes.
- **Explanation**
  SSR allows for more detailed tracking and identification of aircraft, improving airspace management and safety.
- **Examples**
  > ATC sends an interrogation at 1030 MHz; the aircraft transponder replies at 1090 MHz with code and altitude.

  - SSR improves upon primary radar by providing unique identification and altitude data.
- **Considerations**
- SSR requires functioning transponders on aircraft.
- Controllers must know the correct frequencies for interrogation and response.
- **Special Circumstances**
- If an aircraft’s transponder fails, only primary radar returns are available, limiting identification.

SSR Modes: Alpha, Charlie, Sierra

> SSR operates in different modes: Mode Alpha transmits a four-digit code, Mode Charlie adds altitude, and Mode Sierra includes call sign, altitude in 25-foot intervals, and ground status.

- **Keypoints**
  - Mode Alpha: Four-digit code selected by pilot.
  - Mode Charlie: Code plus altitude.
  - Mode Sierra: Call sign, altitude (25-foot intervals), ground/airborne status.
- **Explanation**
  Different SSR modes provide varying levels of information to ATC, with Mode Sierra being the most advanced.
- **Examples**
  > Aircraft with registration GOLD INDIA ZULZUL TANGO, squawk code 1133, climbing and passing flight level 24 (2400 feet).

  - Mode Charlie allows ATC to see both code and altitude.
- **Considerations**
- Pilots must select the correct mode as required by ATC and flight plan.
- Incorrect mode selection can lead to loss of altitude or identification data.
- **Special Circumstances**
- If Mode Sierra is not available, revert to Mode Charlie or Alpha as appropriate.

Transponder Codes and Meanings

> Specific transponder codes are used for standard operations and emergencies: 7000 for VFR in Europe, 7500 for hijack, 7600 for communication failure, 7700 for distress.

- **Keypoints**
  - 7000: Standard VFR code in Europe.
  - 7500: Hijack.
  - 7600: Communication failure.
  - 7700: Distress.
- **Explanation**
  Pilots must know and use the correct codes for their situation. ATC relies on these codes for rapid identification of emergencies.
- **Examples**
  > After a previous flight, pilots must reset the transponder to 7000 for VFR operations using the VFR button.

  - Ensures correct code is transmitted for the current flight.
- **Considerations**

- Always reset to 7000 for VFR outside controlled airspace in Europe.
- Know the emergency codes and use only when appropriate.
- **Special Circumstances**
- If an emergency occurs, select the appropriate code (7500, 7600, or 7700) immediately.

Transponder Operational Modes

> Transponders have several modes: Off, Standby, On (Mode Alpha), Altitude (Mode Charlie/Sierra), Ident, and Test. Each mode determines what information is transmitted to ATC.

- **Keypoints**
  - Off: No transmission.
  - Standby: No response to interrogation.
  - On: Responds with Mode Alpha (code only).
  - Altitude (ALT): Responds with code and altitude.
  - Ident: Highlights aircraft on ATC screen when requested.
  - Test: Used for system checks.
- **Explanation**
  Pilots must select the correct mode based on ATC instructions and flight phase. Ident should only be used when requested by ATC.
- **Examples**
  > When ATC requests, pressing Ident causes the aircraft to flash on the ATC screen for identification.

  - Used for positive identification among multiple targets.
- **Considerations**
- Do not use Ident unless instructed by ATC.
- Ensure correct mode is selected before flight.
- **Special Circumstances**
- If ATC loses your position, check if transponder is in Standby or Off and correct as needed.

Automatic Dependent Surveillance Broadcast (ADS-B)

> ADS-B is a system where aircraft automatically broadcast their position, speed, altitude, and other data using GNSS (GPS) capability. ADS-B Out transmits data; ADS-B In receives data from other aircraft.

- **Keypoints**
  - ADS-B broadcasts aircraft data automatically.

- Requires GNSS capability on board.
- ADS-B Out: Sends data to ground stations and other aircraft.
- ADS-B In: Receives data from other aircraft.
- Operates on 1090 MHz (same as SSR reply).

- **Explanation**
  ADS-B enhances situational awareness for both ATC and pilots, enabling direct aircraft-to-aircraft communication and reducing reliance on ground-based radar.
- **Examples**
  > Aircraft A sends ADS-B Out signal; Aircraft B receives it as ADS-B In, allowing both to know each other's position, speed, and altitude.

  - Improves collision avoidance and traffic awareness.
- **Considerations**
- ADS-B is increasingly required for modern airspace operations.
- Pilots must ensure ADS-B equipment is functioning.
- **Special Circumstances**
- If ground-based SSR is unavailable, ADS-B allows aircraft to maintain situational awareness and separation.

Impact of Weather and Terrain on Radar

> Weather (especially intense precipitation) and terrain can cause clutter and errors in radar displays, potentially obscuring real targets or creating false returns.

- **Keypoints**
  - Intense precipitation can clutter radar displays.
  - Terrain can reflect radar signals, causing permanent clutter.
  - Modern radar systems use filters to remove unnecessary returns.
- **Explanation**
  Controllers must be aware of environmental factors that can affect radar accuracy and use filtering technology to mitigate their effects.
- **Considerations**
- Monitor weather conditions and adjust radar filters as needed.
- Be cautious of clutter in areas with significant terrain.
- **Special Circumstances**
- If thunderstorms or heavy precipitation are present, expect increased clutter and use filtered displays.

Automatic Direction Finding (ADF) and Non-Directional Beacon (NDB)

> ADF is a navigation system that uses NDBs (Non-Directional Beacons) to determine the direction to a ground station. The system displays the direction to the NDB using a needle on the aircraft's heading indicator. NDBs operate on different frequencies than VORs and are still used in some older aircraft.

- **Keypoints**
  - ADF systems use NDBs for navigation.
  - The ADF needle indicates the direction to the NDB relative to the aircraft's heading.
  - NDBs are represented on maps as a circle with dots around it.
  - Still used in older aircraft such as old Cessnas and Pipers.
- **Explanation**
  When the pilot tunes into an NDB frequency, the ADF needle appears on the heading indicator, showing the direction to the NDB. The system is simple but requires understanding of how to interpret the needle and compass card, especially in older aircraft where the compass card may not be synchronized with the heading indicator.
- **Examples**
  > A pilot tunes the ADF to an NDB frequency. The needle on the heading indicator points towards the NDB. The pilot uses this information, along with the aircraft's heading, to navigate directly to the station.

  - Tune the ADF to the desired NDB frequency.
  - Observe the needle on the heading indicator.
  - Adjust the aircraft's heading to keep the needle centered, flying directly to the NDB.
- **Considerations**
- Some aircraft have fixed compass cards that require manual adjustment.
- The system is susceptible to errors if the compass card is not synchronized with the heading.
- **Special Circumstances**
- If the compass card is not synchronized with the heading indicator, manually align the card before using the needle for navigation.

Relative Bearing Indicator (RBI)

> The RBI is an instrument that shows the direction of the NDB relative to the aircraft's nose. It is a vertically mounted compass card with a needle. The RBI can be fixed or synchronized with the aircraft's heading. The RBI is an older system, still found in some aircraft.

- **Keypoints**

  - RBI shows the direction to the NDB relative to the aircraft's heading.
  - The compass card may be fixed or synchronized with the heading.
  - If not synchronized, the pilot must manually align the card or use a parallel transfer method to determine the magnetic bearing.
  - The RBI is used to find QDM (bearing to the station) and QDR (radial from the station).
- **Explanation**
  To use the RBI, the pilot observes the needle's position relative to the compass card. If the card is not synchronized, the pilot can use a pen to transfer the needle's direction to the heading indicator and read the QDM. If the card is synchronized, the QDM can be read directly from the RBI.
- **Examples**
  > The pilot uses a pen to transfer the needle's direction from the RBI to the heading indicator, then reads the QDM at the tip of the pen.

  - Place the pen along the RBI needle.
  - Move the pen parallel to the heading indicator.
  - Read the QDM at the tip of the pen.
  > The pilot sets the RBI compass card to match the aircraft's heading, then reads the QDM directly from the RBI.

  - Align the RBI compass card with the aircraft's heading (e.g., set 330 on the RBI if heading is 330).
  - Read the QDM directly from the RBI.
- **Considerations**
- If the RBI is not synchronized, extra steps are needed to determine the correct bearing.
- Errors can occur if the compass card is not properly aligned.
- **Special Circumstances**
- If the RBI compass card does not update with heading changes, manually rotate the card or use the parallel transfer method to find the correct bearing.

Magnetic Bearing, Magnetic Heading, and Relative Bearing

> Magnetic bearing is the direction to the station measured clockwise from magnetic north. Magnetic heading is the direction the aircraft's nose is pointing, also measured from magnetic north. Relative bearing is the angle between the aircraft's heading and the direction to the station.

- **Keypoints**
  - Magnetic bearing is measured from magnetic north to the station.
  - Magnetic heading is the aircraft's direction relative to magnetic north.

    - Relative bearing is the angle between the aircraft's heading and the station.
    - Formula: Magnetic bearing = Magnetic heading + Relative bearing.
- **Explanation**
  To find the magnetic bearing to a station, add the aircraft's magnetic heading to the relative bearing indicated by the RBI. If the sum exceeds 360, subtract 360 to get the correct bearing. This formula is essential for navigation using NDBs and RBIs.
- **Examples**
  > If the aircraft's heading is 170 degrees and the relative bearing is 300 degrees, the magnetic bearing to the station is 170 + 300 = 470. Subtract 360 to get 110 degrees.

    - Heading: 170 degrees
    - Relative bearing: 300 degrees
    - 170 + 300 = 470
    - 470 - 360 = 110 degrees (magnetic bearing to the station)

  > If the magnetic bearing to the station is 090 and the heading is 180, the relative bearing is 090 - 180 = -90. Add 360 to get 270 degrees (relative bearing to the left).

    - Magnetic bearing: 090
    - Heading: 180
    - 090 - 180 = -90
    - -90 + 360 = 270 degrees (relative bearing to the left)
- **Considerations**
- Always use the correct formula and adjust for values over 360 or below 0.
- Wind can cause the heading to differ from the track, affecting calculations.
- **Special Circumstances**
- If the sum of heading and relative bearing exceeds 360, subtract 360 to get the correct magnetic bearing.
- If the result is negative, add 360 to get the correct angle.

QDM and QDR

> QDM is the magnetic bearing to the station (the direction to fly to reach the station). QDR is the radial from the station (the magnetic line extending from the station).

- **Keypoints**
    - QDM is the magnetic bearing to the station.
    - QDR is the radial from the station.
    - QDM can be found by adding the heading and relative bearing.
    - QDR is read from the tail of the needle.

- **Explanation**
  To find QDM, use the tip of the RBI needle and the formula. To find QDR, use the tail of the needle. Remember that QDR represents the radial you are currently on, extending from the station.
- **Examples**
  > If the RBI needle points to 045, the QDM is 045. The QDR is read from the tail of the needle.

  - Look at the tip of the RBI needle for QDM.
  - Look at the tail of the RBI needle for QDR.
- **Considerations**
- Remember the difference between QDM (to the station) and QDR (from the station).
- **Special Circumstances**
- If unsure, remember the mnemonic: QDR = Radial (R for radial).

Impact of Wind on Heading and Track

> Wind can cause the aircraft's heading to differ from its track, affecting navigation calculations. The relative bearing is the angle between the aircraft's heading and the track to the station.

- **Keypoints**
  - Wind can push the aircraft off its intended track.
  - The heading may need to be adjusted to compensate for wind.
  - Relative bearing is affected by the difference between heading and track.
- **Explanation**
  If the wind is coming from the left, the pilot must fly with the nose to the left to maintain the desired track. This creates a difference between heading and track, which is reflected in the relative bearing.
- **Examples**
  > If the wind is from the left, the pilot must fly with the nose to the left to stay on track. The relative bearing will show the angle between the heading and the track.

  - Identify wind direction.
  - Adjust heading to compensate for wind.
  - Observe the change in relative bearing.
- **Considerations**
- Always account for wind when calculating heading and track.
- **Special Circumstances**
- If experiencing unexpected drift, check wind direction and adjust heading accordingly.

Compass Card and RBI Interpretation

> The compass card on the RBI (Radio Bearing Indicator) displays cardinal headings: 360, 090, 180, and 270. The orientation of the aircraft relative to the station is determined by the position of the needle and the compass card.

- **Keypoints**
  - Compass card shows 360, 090, 180, 270.
  - If 90 degrees to the right of the station, needle shows accordingly.
  - Relative bearing is calculated based on aircraft and station positions.
- **Explanation**
  The instructor explained that the compass card is used to interpret the aircraft's heading relative to the station. For example, if the aircraft is 90 degrees to the right of the station, the relative value will be 270.
- **Considerations**
- Always check the compass card orientation before interpreting the needle.

NDB Frequencies and Identification

> NDBs (Non-Directional Beacons) always have three-digit frequencies, such as 345 or 368. These frequencies can be found in the AIP, charts, or maps. Each NDB has a unique Morse code identifier, which should be checked to ensure the correct station is tuned.

- **Keypoints**
  - NDB frequencies are always three digits (e.g., 345, 368).
  - Frequencies can be checked in the AIP, charts, or maps.
  - Each NDB has a Morse code identifier displayed on charts.
  - Pilots should listen to the Morse code and compare it with the chart.
- **Explanation**
  The instructor gave the example of the Vitoria NDB (Victor Tango Alpha, frequency 345) and explained how to identify it using Morse code. The Morse code for each station is shown on the chart next to the station name.
- **Examples**
  > In Vitoria, after taking off from runway 04, there is an NDB called Victor Tango Alpha with frequency 345. The Morse code identifier for this NDB is shown on the chart and should be verified by listening.

  - Locate the NDB on the chart.
  - Tune the frequency 345.
  - Listen to the Morse code identifier.
  - Compare the Morse code with the chart to confirm correct station.

- **Considerations**
- Always verify the Morse code identifier before using the NDB for navigation.
- **Special Circumstances**
- If the Morse code does not match the chart, do not use the NDB for navigation.

ANT Selector and ADF Needle Behavior

> The ANT selector is used for identifying the NDB. When ANT is selected, the ADF needle does not provide bearing information and is only used for identification or listening to the Morse code.

- **Keypoints**
  - ANT selector disables bearing indication on the ADF needle.
  - Used for identification or listening to Morse code.
  - Not limited to NDBs; also applies to VORs.
- **Explanation**
  The instructor explained that with ANT selected, the ADF needle will not show bearing information. This is useful for identification purposes only.
- **Considerations**
- Do not rely on ADF needle for navigation when ANT is selected.

NDB Signal Propagation and Errors

> NDBs operate in low and medium frequency bands, which have longer wavelengths and can follow the curvature of the earth. This makes them susceptible to various errors, including surface error, precipitation static, coastal refraction, night effect, and thunderstorm interference.

- **Keypoints**
  - LF and MF bands allow signals to follow earth's curvature.
  - Surface error: signals travel further over smooth sea than irregular terrain.
  - Precipitation static: rain, snow, or clouds can reduce signal strength.
  - Coastal refraction: signal deflection when crossing coastline at non-90-degree angles.
  - Night effect: increased range but decreased accuracy due to sky wave reflection from the ionosphere.
  - Thunderstorm effect: ADF needle may point to thunderstorms instead of NDB.
- **Explanation**
  The instructor detailed each error type, explaining how surface conditions, weather, and time of day affect NDB signal accuracy and range. For example, at night, the ionosphere lowers, causing sky waves to reflect and increase range but reduce accuracy.

- **Examples**
  > When an NDB signal crosses the coastline at an angle other than 90 degrees, the signal is refracted due to different propagation speeds over land and sea, causing bearing errors.

  - Aircraft is near the coastline.
  - NDB signal crosses from sea to land at a non-90-degree angle.
  - Signal is refracted, causing the instrument to show an incorrect position.

  > At night, the ionosphere lowers, causing some NDB signals to reflect back to earth as sky waves, increasing range but decreasing accuracy.

  - During night, ionosphere altitude decreases.
  - Sky waves reflect from the ionosphere.
  - NDB range increases, but accuracy decreases due to multiple signal paths.
- **Considerations**
- Prefer VORs over NDBs at night due to increased errors.
- Avoid using NDBs during thunderstorms; use GPS or VOR if possible.
- **Special Circumstances**
- If encountering thunderstorms, use GPS or VOR instead of NDB for navigation.
- If operating near the coast, minimize coastal refraction by using NDBs close to the coast and crossing the coastline at angles as close to 90 degrees as possible.

Bearings and Headings: Definitions and Formulas

> Magnetic bearing, magnetic heading, and relative bearing are key concepts in navigation. The relationships between them are defined by formulas: Magnetic bearing = Magnetic heading + Relative bearing; Relative bearing = Magnetic bearing - Magnetic heading.

- **Keypoints**
  - Magnetic bearing: measured from magnetic north to the station.
  - Magnetic heading: measured from magnetic north to the aircraft’s nose.
  - Relative bearing: measured from the aircraft’s nose to the station.
  - Formulas: Magnetic bearing = Magnetic heading + Relative bearing; Relative bearing = Magnetic bearing - Magnetic heading.
- **Explanation**
  The instructor emphasized the importance of drawing diagrams to visualize bearings and headings. Several quiz examples were solved using these formulas, including handling negative results by adding 360 to obtain a positive bearing.
- **Examples**
  > An aircraft is tracking directly away from an NDB on a QDR of 290, experiencing a 10-degree port drift. The task is to find the relative bearing.

    - QDR is 290; port drift means wind from the right, so heading is 300.
    - Magnetic bearing = 110 (opposite of QDR).
    - Relative bearing = Magnetic bearing - Magnetic heading = 110 - 300 = -190.
    - Add 360 to get positive value: -190 + 360 = 190.

    > Aircraft is tracking away from NDB on 050, experiencing 10-degree starboard drift. Find the relative bearing.

    - QDR is 050; starboard drift means wind from the left, so heading is 040.
    - Magnetic bearing = 230 (opposite of QDR).
    - Relative bearing = Magnetic bearing - Magnetic heading = 230 - 040 = 190.
- **Considerations**
- Always draw diagrams for navigation problems.
- Use the formulas consistently to avoid errors.
- **Special Circumstances**
- If the calculated bearing is negative, add 360 to obtain a positive value.

QDR and QDM Definitions

> QDR is the magnetic bearing from the station to the aircraft (track from the station). QDM is the magnetic bearing to the station (track to the station).

- **Keypoints**
    - QDR: Magnetic bearing from the station to the aircraft.
    - QDM: Magnetic bearing to the station.
- **Explanation**
  The instructor clarified the difference between QDR and QDM, emphasizing their use in navigation and quiz questions.
- **Considerations**
- Use QDR and QDM correctly in calculations.

Conspicuity Codes for VFR Flight

> The conspicuity code for VFR flight in the UK is 7000. Previously, 2000 was mentioned, but 7000 is the standard for both the UK and Europe.

- **Keypoints**
    - UK and Europe VFR conspicuity code: 7000.
    - 2000 was mentioned but 7000 is correct.
- **Explanation**
  The instructor corrected the code during the discussion, confirming that 7000 is the correct code for VFR conspicuity in the UK and Europe.
- **Considerations**

- Always use 7000 as the VFR conspicuity code in the UK and Europe.

Assignments & Suggestions

- Take a picture of the formula: Magnetic bearing = Magnetic heading + Relative bearing.
- Watch the videos about RBI provided by the instructor.
- Prepare for two quiz questions on RBI and practice together in the next lesson.