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DOCUMENT TITLE

CPL NAVIGATION 2 (AUSTRALIA)

CHAPTER 5 – AUTOMATIC DIRECTION FINDING

Version 2.1
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AUTOMATIC DIRECTION FINDING (ADF)

5.1 Introduction

The Non-Directional Beacon (NDB) is a radio navigation aid whose origins date back to the Second World War.

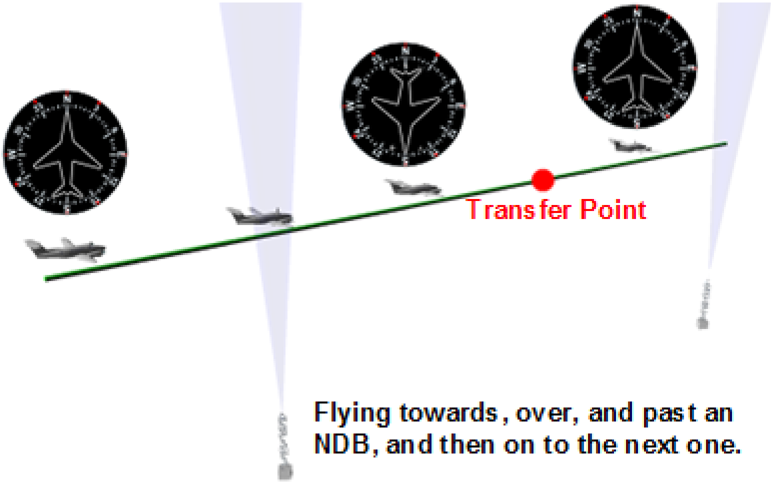
It comprises of two components. The NDB is the term used to describe the ground station and the airborne equipment is known as the Automatic Direction Finder or ADF.

The ADF receives the signals transmitted from the beacon and displays navigation information on a suitable indicator. The needle on the indicator shows the bearing to the NDB.

Combined with heading information from the compass or DI, the crew can orientate themselves in relation to the station.

5.2 The NDB

The NDB is used for en route navigation, tracking, homing and instrument approaches.

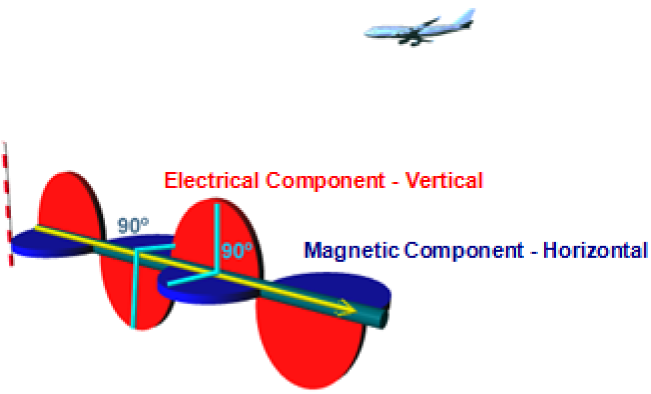


The combination of ADF needle and Directional gyro/compass becomes extremely useful to assist the pilot when navigating with reference to the NDB.

The NDB can be used to track to the station on any desired bearing, pass overhead and then track outbound on whatever bearing is required. It can also be used to fix the aircraft's position.

5.2.1 Signal Characteristics

As the name implies NDBs transmit signals that are radiated equally in all directions.



The transmissions from the beacon are vertically polarised signals.

This means the receiving antenna on the aircraft needs to be in the vertical plane for best reception.

5.2.2 Frequency Band

The requirement for the NDB transmitter is to provide adequate surface ranges. This is achieved by transmitting in the upper half of the low frequency (LF) band and the lower half of the medium frequency (MF) band, where strong ground waves are found.

The advantages of transmission at these frequencies are:

- In this frequency range aircraft antenna length requirements are acceptable.
- Static interference is less than in the very low frequency (VLF) band.
- No interference from sky waves during day time.
- Even though operation is in the LF/MF band, the required ranges are still achieved.

By convention the NDB is a medium frequency navigational aid. Frequencies assigned by the International Civil Aviation Organization (ICAO) are 200 kHz to 1750 kHz. However, the frequencies commonly used for international NDB transmissions are between 200 kHz and 500 kHz.

5.2.3 The Range of the NDB

NDB's have a range of 10nm to 500nm.

The range of the NDB also depends on various factors which include:

Transmitter power, transmitter frequency, type of terrain and emission type. The complete list of factors is explained in the NDB range and accuracy section of this chapter.

5.2.4 Types and Uses of the NDB

5.2.4.1 Locators

These are low powered NDBs (25-100 watts) and can be used as a supplement to the instrument landing system (ILS).

These beacons are placed along the runway centreline at specific distances from the runway threshold and are referred to as the outer, middle and inner markers.

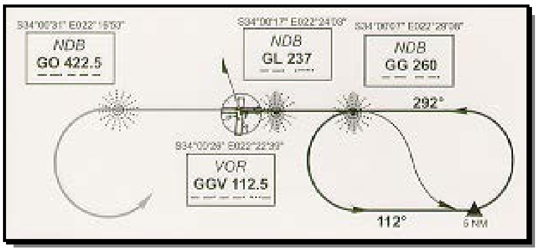
The purpose of these marker beacons is to provide an indication in the cockpit when the aircraft passes over them so that the pilot is aware of the distance from the runway in limited visibility conditions.

The radius of coverage is 10 nm to 25 nm and identification is by a two or three letter Morse code group.

Note: The term locator has been removed from ICAO terminology. The beacons are now referred to as NDBs. Their power and range not changed.

5.2.4.2 NDB

These beacons can provide guidance for instrument approaches or for en-route navigation along airways. Their maximum range is 500nm.



By placing these beacons along an airway between two airfields, it allows the pilot to navigate with reference to the radio signals emitted by the beacons, especially when visual navigation is not possible due to bad weather, obscuring the terrain below the aircraft or at night.

The station identification is broadcast at least once every minute in the form of a 2 or 3 digit Morse code group.

5.2.4.3 AM Broadcast Stations

AM broadcast stations are commercial radio stations which transmit within the same frequency band (500 to 1600 kHz) as the NDB and bearings to these broadcast stations can be displayed on the ADF in a similar manner as bearings to NDB stations are displayed.

Information pertaining to AM broadcast stations can be found in the ERSA NAVCOMM 3 section or in the Jeppesen Radio Aids section page AU13. Below is an extract from the Jeppesen manual:

Aviation authorities do not issue NOTAM for broadcast stations. It is possible that the information listed may be inaccurate. The station identification is the general location of the reception area and is not necessarily the site of the transmitter. Coordinates shown apply to position of transmitter. Note that the datum used is not WGS84 but Australian Geodetic Datum 1966 (AGD66). CAUTION: A considerable number of stations relay broadcasts.

STATION	IDENT	FREQ (KHZ)	PSN LAT LONG	POWER
AUSTRALIAN CAPITAL TERRITORY				
Canberra	2CN	666	S35 13 09 E149 07 21	5k
Canberra	2RN	846	S35 13 09 E149 07 21	10k
Canberra		1008	S35 13 15 E149 06 58	300
Canberra	2CA	1053	S35 13 20 E149 08 53	5k
Canberra	1RPH	1125	S35 13 00 E149 07 00	2k
Canberra	2CC	1206	S35 13 09 E149 07 21	5k
Canberra	2PB	1440	S35 13 09 E149 07 21	2k
NEW SOUTH WALES				
Albury		1296	S36 03 22 E146 57 48	540
Albury	2AY	1494	S36 03 22 E146 57 48	2k
Armidale	2RN	720	S30 29 51 E151 39 49	50
Armidale	2AD	1134	S30 32 48 E151 36 07	2k
Bathurst	2BS	1503	S33 22 22 E149 32 09	5k
Bega	2EC	765	S36 44 41 E149 56 16	4k
Bega	2BA	810	S36 42 47 E149 49 10	10k
Bourke	2WEB	585	S30 06 09 E145 58 51	5k
Bowral	2ST/T	1215	S34 29 35 E150 23 54	350
Broken Hill	2BH	567	S31 56 25 E141 26 36	500
Broken Hill	2NB	999	S31 55 48 E141 29 06	2k
Byrock	2BY	657	S30 39 04 E146 25 33	10k
Cobar	2DU/T	972	S31 31 01 E145 50 07	300
Coffs Harbour	2CS	639	S30 28 19 E153 01 53	5k
Cooma	2XL	918	S36 14 23 E149 08 56	2k
Cooma	2CP	1602	S36 13 45 E149 08 08	50

5.2.4.4 Precautions When Using AM Broadcast Stations

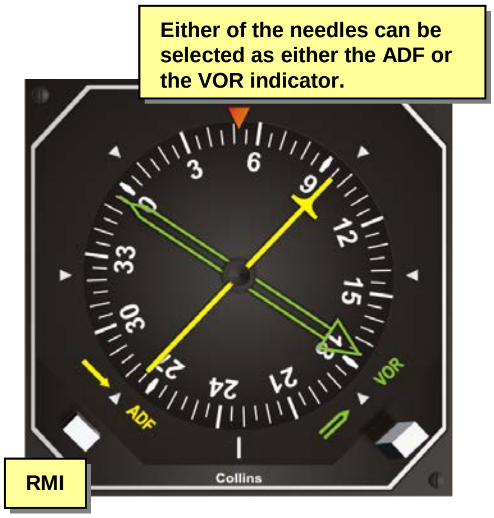
AM broadcast stations can be a source of information, providing information such as upcoming weather conditions and must be used with caution:

- These transmissions are not monitored or regulated by CASA and there is no NOTAM service in terms of conditions of operation.

- Stations can be difficult to identify, since many stations are networked and may broadcast programs from other (relay) stations.
- The nature of the broadcast (music, sport, news, etc.) can be a source of distraction in the cockpit.
- The transmissions from these stations are unreliable due to restricted broadcast times and in some cases; no standby power is available in the event of a power failure.

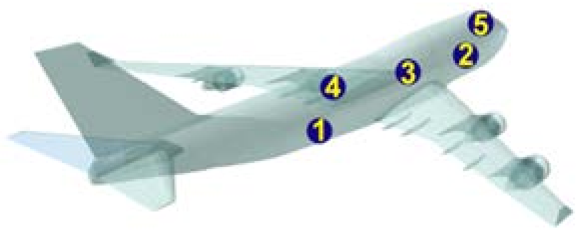
5.3 The ADF

The direction of the radio waves may be shown on a Relative Bearing Indicator (RBI) with bearing information referenced to the nose of the aircraft, or on a Remote Magnetic Indicator (RMI) displays magnetic bearings to the source of the radio waves.



5.3.1 Airborne Equipment

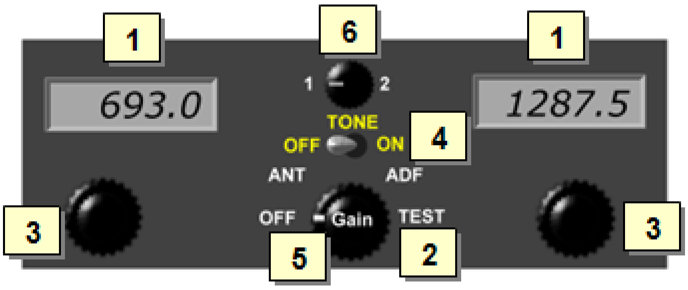
Although there are a great variety of manufactures of ADFs on the market, all basically contain the same main components:



- ***(1) -*** A receiver operating in the LF/MF frequency bands.
- ***(2) -*** A control unit.
- ***(3) -*** A shielded fixed or rotatable loop aerial.
- ***(4) -*** Sense aerial (non-directional aerial).
- ***(5) -*** One or more indicators.

5.3.1.1 Controls

Although all ADFs have the same basic controls, ADFs do not all have the same features.



- ***(1) -*** Frequency display window
- ***(2) -*** Function control switch
- ***(3) -*** Frequency selector
- ***(4) -*** Tone selector
- ***(5) -*** Audio Gain control
- ***(6) -*** Transfer (TFR) switch

5.3.1.2 Functions

OFF - The set is switched off and no bearing information will be displayed.

ANT - Only the sense aerial is in use. Audio quality should be better than when the ADF position is selected. This assists with the tuning of the station, also named REC (receiver), OMNI or SENSE, depending on the manufacturer.

ADF - Both loop and sense aerials are in operation. The ADF indicates a continuous bearing to the station tuned to.

Voice messages transmitted with the signal (such as ATIS) can be unreadable due to the alternating current flowing through the loop antenna when the function switch is in this position, therefore switch the function switch momentarily to the **ANT** position to listen to the ATIS.

Switching the function switch away from the **ADF** position will prevent the system from displaying YXG4UWUD4Mbearing information.

TEST - Used to loop (turn away) the needle from the beacon and a specific indication must appear on the display unit for the system to be functional. When switching to ADF the needle should return to its previous position.

5.3.1.3 TONE or BFO

The Tone switch is also known as the beat frequency oscillator (BFO). The Tone or BFO switch makes N0N A1A Carrier Wave type NDB emissions audible.

For these types of emissions, the equipment creates an audio signal inside the receiver and this is mixed with the received radio signal. An audible tone is produced, which is transmitted in long and short tones for the Morse coding used to identify the station.

For example if the frequency received is 300 kHz, the BFO will produce a frequency of 299 kHz. It then emits the difference between the two frequencies (in the example 1 kHz), which is audible and is known as the beat note. With the BFO selected ON this note is audible whenever the N0N A1A signals are being received and the station identifier can be heard.

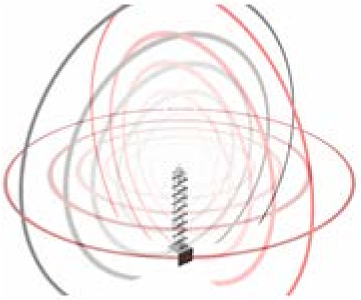
Use of BFO Switch

It should be noted that N0N A1A transmissions are broken up during identification by the on-off keying of the carrier wave. This can cause the ADF needle to wander. For this reason the BFO must be selected to OFF, whenever a bearing needs to be obtained.

TYPE OF EMISSION	TO HEAR TONE FOR TUNING	TO HEAR IDENTIFICATION
N0N A1A	BFO ON (CW)	BFO ON (CW)
N0N A2A	BFO ON (CW)	BFO OFF (VOICE)
A2A A3E	BFO OFF (VOICE)	BFO OFF (VOICE)

In most ICAO countries different emission standard are used for the NDB and the BFO switch does not need to be used for station identification.

5.4 NDB Principle of Operation



The NDB radiates identical electromagnetic energy in all directions. NDBs have given frequency, which is normally in the low- and medium frequency range, 200 kHz – 1750 kHz.

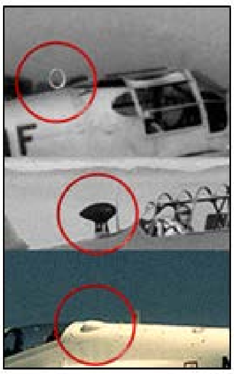
The transmission mast can either be a single mast or a large T-Type antenna suspended between two masts.

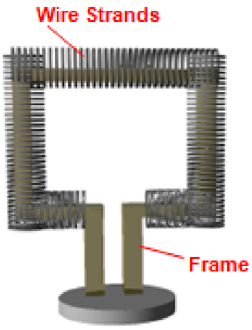
A NDB transmits an identification signal in the form of a two or three-lettered Morse code signal. The pilot should monitor this identification to ensure that the correct NDB is being utilized.

The ADF equipment indicates the direction of the station by receiving the signal through two antennas, known as Loop and Sense antennas. The functions are described below.

The principle on which the operation of NDB is based is called Loop Theory

5.4.1 Loop Antenna Construction





The loops can be circular or rectangular and is mounted vertically on the fuselage. A number of strands of wire are wound around the frame. This wire receives the radio signal and is of appropriate length for the range of frequencies that can be selected.

The original loops were fixed to the aircraft fuselage with later designs able to be rotated by a crew member from inside the aircraft. These antennae were covered by a fairing to reduce drag.

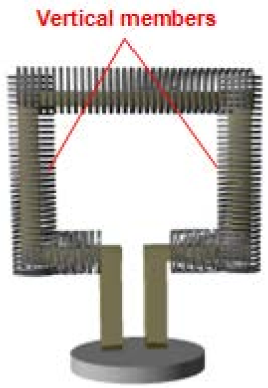
Modern equipment utilises smaller fixed antennae placed into smaller streamlined housings located on the fuselage.

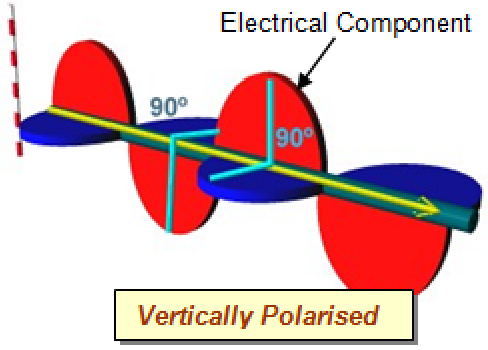
The frame can either be rectangular or circular and mounted vertically on the fuselage.

5.4.2 Principle of Operation - Rotating Loop Antenna

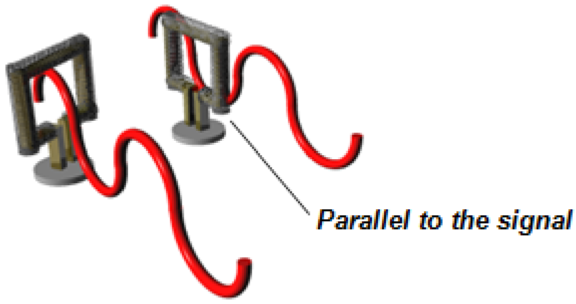
A loop antenna is used in the aircraft to determine the direction of the ground transmitter (NDB).

As NDB signals are vertically polarised the signals are received by the vertical members of the loop antenna.



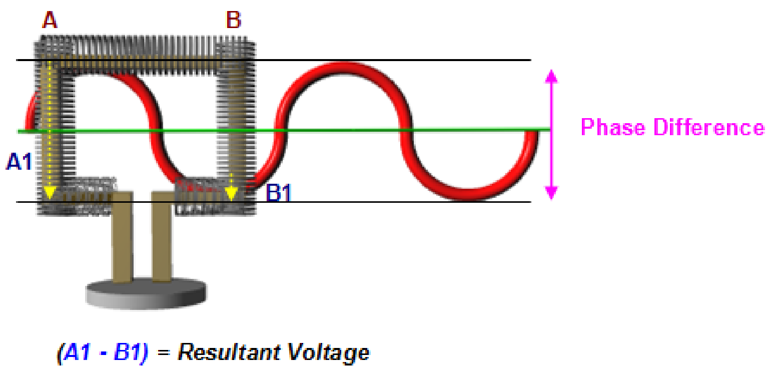


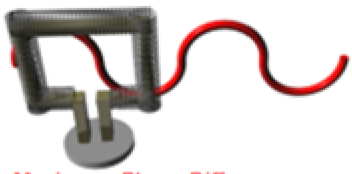
Maximum signal is received when the loop is orientated parallel to the radio wave.



Due to the distance between the vertical members of the loop, there is a phase difference between the signals arriving at the two arms.

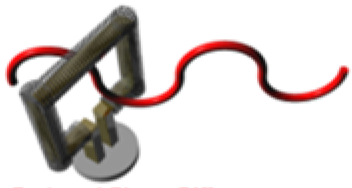
This causes a difference in voltage across the loop due to opposition current flow in the arms and the resultant signal is sent to the receiver.





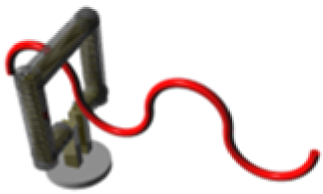
Maximum Phase Difference

When the loop is in a parallel orientation with the incoming wave, the distance between the two arms is at a maximum. The phase difference and therefore the resultant current flow to the receiver is also at a maximum.



Reduced Phase Difference

If the loop is rotated through 45°, the phase difference and therefore the current to the receiver is reduced.

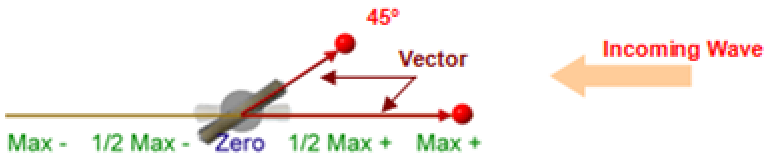


Zero Phase Difference

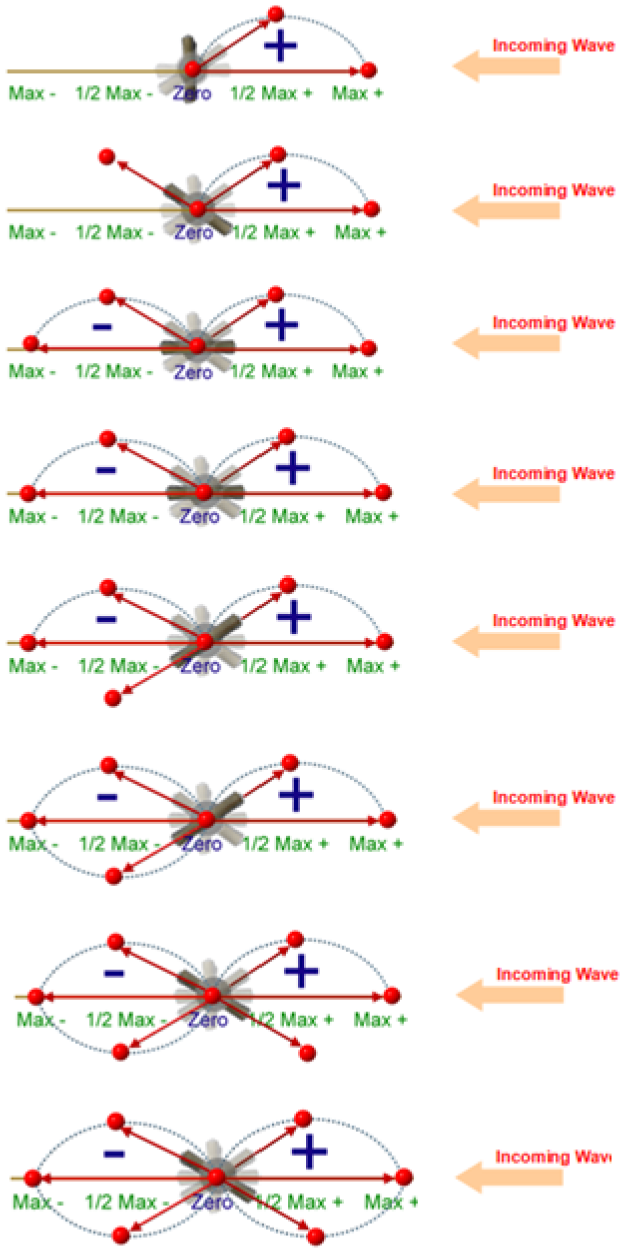
If the loop is rotated through 90° (perpendicular to the wave), the incoming wave reaches both arms at the same time and there will be no phase difference and no resultant current to the receiver.

By rotating the loop through 360°, a signal strength pattern can be traced (polar diagram), which indicates the phase differences between maximum and minimum values.

The vector below is representative of the phase difference at 45° intervals, and started at a maximum value when the antenna was parallel to the incoming wave.



Rotating the loop anti-clockwise through 45° will result in a reduced current.



When the loop is rotated through 90°, the incoming wave reaches both arms at the same time and therefore no phase difference or voltage is sensed.

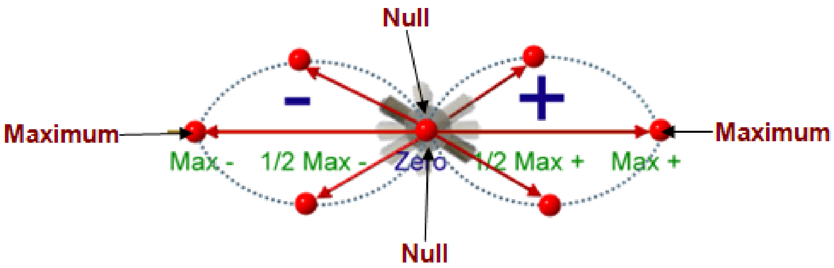
No current flows to the receiver when the loop is perpendicular to the incoming wave. This is called the null position.

The vectors plotted thus far have all been positive.

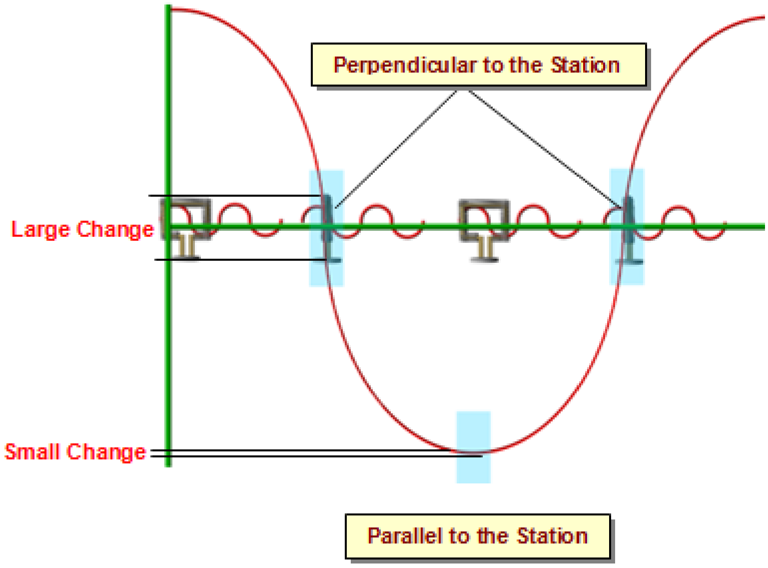
From 90° to 180°, the value changes from positive to negative.

Once the aerial has rotated through 360°, the resulting vector diagram is a figure of eight, with positive values to the right and negative values to the left.

The polar diagram has two positions where a maximum signal is generated and two null positions.



When establishing the direction of a ground station, the loop could be aligned parallel to the incoming signal, reading the maximum signal as the direction of the station.

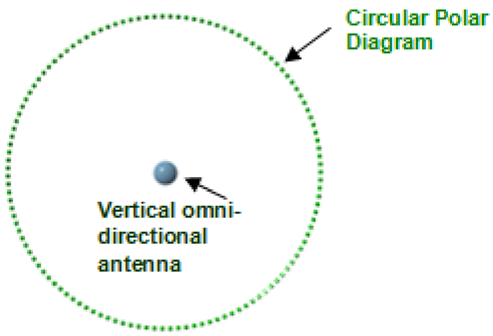


As can be seen though, the signal strength falls away slowly either side of the maximum position and this would reduce the accuracy of the indications, if this position was used as reference.

With reference to the above diagram, the signal increases quite rapidly either side of the null positions which gives a more definite indication of the station direction and therefore the null position is used to indicate direction.

5.4.3 Ambiguity and Use of the Sense Antenna

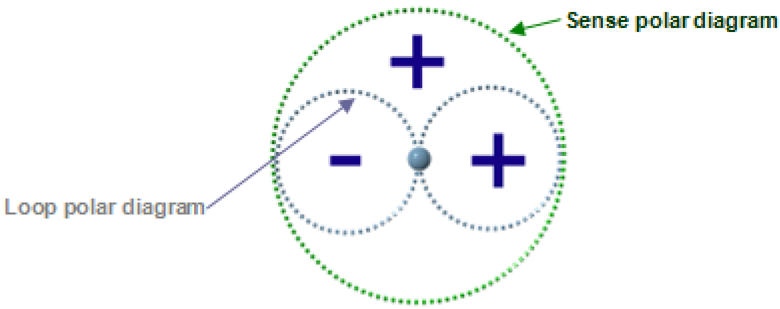
During one complete rotation of the loop antenna two null points will be detected. This produces a 180° ambiguity as only one of these null points indicates the correct direction to the station. This ambiguity is resolved by the use of the sense antenna and its Omni directional sensing capabilities.



The sense antenna has a circular polar diagram.

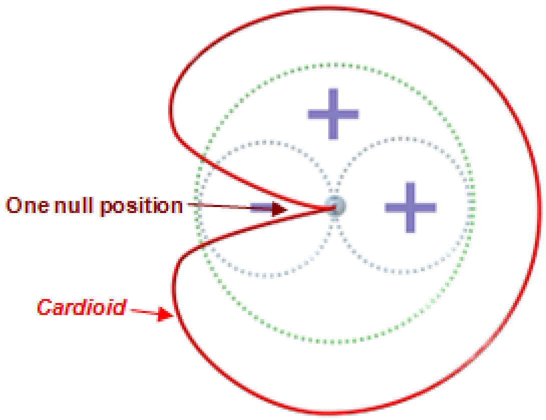
5.4.3.1 Resolution of Ambiguity

The radius of the sense antenna's polar diagram is adjusted electronically to fit exactly on top of the loop antenna's polar diagram.



The combination of the two polar diagrams results in a heart shaped diagram known as a **cardioid**.

It will be noticed that the cardioid only has one null position.

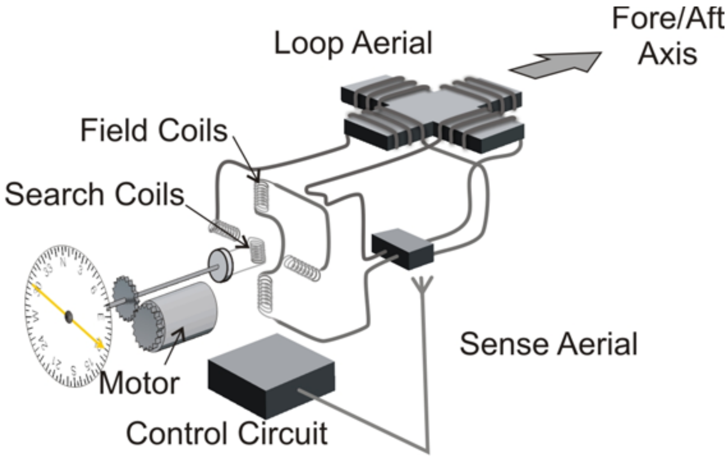


The null position is definite enough to give accurate indication of direction and the problem of ambiguity has been resolved.

5.4.4 Principle of Operation - Fixed Loop Antenna (Bellini-Tosi Method)

Modern ADF equipment replaces the rotating loop with a pair of fixed loops 90° apart; one aligned with the longitudinal axis of the aircraft and the other with the lateral. As the wave flows past the loops, current is induced in the loops and flows through to the field coils.

The current flowing though the field coil induces a magnetic field across the coils. A search coil is positioned in between the field coils; it is a null seeking coil. This means if the search coil is not orientated 90° to the magnetic field surrounding it a voltage is induced into the coil. A motor then drives the sense coil to the 90° position to reduce the voltage in the coil to zero.



The coil can be driven to either one of two null points therefore the signal from the sense antenna is used to resolve this 180° ambiguity. The ADF needle is connected to the motor which drives the sense coil so it will indicate the correct direction to the station.

This combination of loops and coils is known as a goniometer (derived from Greek meaning: “angle measure”). The material that the fixed loops are wound around is known as a “Ferrite Cross”.

5.5 The NDB - Range and Accuracy

As with all radio navigation systems the NDB/ADF has certain limitations that flight crew need to be made aware off prior to use.

5.5.1 Factors Affecting the Range of NDB Transmissions

The range of NDB transmissions are varied and are affected by the following factors:

- Transmission power
- Frequency
- Terrain
- Night effect
- Protection range or designated operational coverage

- Static error or thunderstorm effect
- Type of emission
- Effect of aircraft height.

5.5.1.1 Transmission Power

Increased power results in increased range, therefore powerful NDBs operating at 10 kilowatts can achieve ranges as great as 500 nm.

Range is considered to be proportional to the square root of power and thus to double the range of an NDB transmitter, the power output would have to be increased four times.

Therefore a relatively **large change in power** output is needed in order for a **small change in the range** to be achieved.

It must also be remembered that the power output of a NDB station is purposefully limited to a value that will produce the required signal strength at the maximum rated coverage boundary.

5.5.1.2 Frequency

For a given transmitter power, lower frequencies suffer less surface attenuation than higher frequencies and therefore produce greater ground wave ranges.

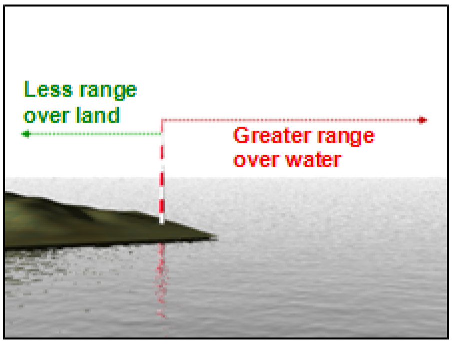
In Australia most NDBs have frequencies between 200 kHz and 400 kHz to maximise ground wave range.

Beacons situated in mountainous areas often have higher frequencies (e.g. 1600 kHz) in order to limit the amount of reflected signals.

5.5.1.3 Terrain

The type of terrain in the vicinity of the beacon affects both range and accuracy and effects transmissions as follows:

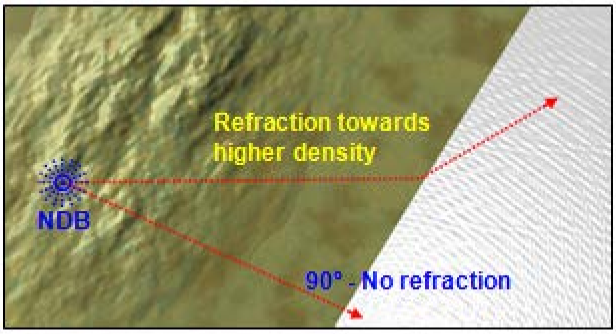
- Type of surface. Useful range is affected by the different rates of attenuation over different surfaces. Maximum range is achieved when the ground wave travels over water and is greatly reduced when the surface is soil or dry sand.



- Mountains and other obstructions. ADF systems may be subject to errors caused by the reflection and refraction of the signal in mountainous areas.

Refer to the Jeppesen Radio Aids section, page AU1 par 2.2 for more information on NDB signal reflections in mountainous terrain.

- Coastal Refraction. If a wave travels from an NDB on the land to the sea and crosses the coastline at 90°, it will not be affected by coastal refraction.



If the wave should cross the coastline at any angle other than a right angle, it will bend towards the medium of highest density (in this case the land). The wave also experiences a slight increase in speed as well as wavelength.

As the angle between the wave and the coastline increases or decreases, the angle of refraction increases and the radio wave can be deviated by as much as 20°.

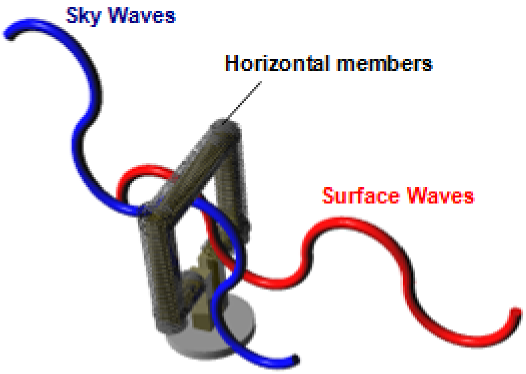
The amount of refraction experienced by the radio wave is increased the further the beacon is situated inland of the coast.

An aircraft tracking over water toward an NDB will experience greater refraction of the received signal when flying at low altitude compared to high altitudes.

5.5.1.4 Night Effect (Sky Wave Error)

The NDB transmits signals in the LF-MF frequency bands. By day the sky wave components of sky wave signals are attenuated by the ionosphere and not refracted back to earth.

At night however as the ionosphere is weaker the sky waves are refracted back to earth.



This can cause the sky and surface waves to mix and will produce fading of the signal if the received radio waves are 180° out of phase.

This causes erroneous readings from the ADF in the form of an oscillating needle.

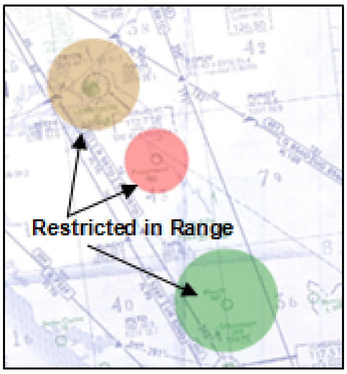
Alternatively the ADF receiver may only receive the sky wave. The sky wave will be detected by the horizontal component of the loop antenna rather than the vertical. This causes a distortion of the cardioid polar diagram and results in bearing errors.

Night effect can be minimised in the following ways:

- Use a station in the lower section of the frequency band, reducing the possibility of sky waves.
- Dusk and dawn are critical periods for night effect and the ADF must be used with caution during these periods.
- Use a more powerful beacon if available and use the beacon closest to you.

5.5.1.5 Protection Range or Designated Operational Coverage (DOC)

Irrespective of the range that an NDB is capable of producing, the use of an NDB is restricted to a limited or protected range. This is known as **Designated Operation coverage (DOC)**.



This restriction is necessary in order to provide reception free from interference from other NDBs transmitting on the same or similar frequencies.

> **Note**: In Australia the published ranges of all NDBs can be found in the ERSA or Jeppesen Radio Aids section and take into account ground stations that are in close proximity to one another other. Rated coverage is discussed later in this chapter.

5.5.1.6 Static Error or Thunderstorm Effect

Precipitation can cause static interference, reducing the range and accuracy of heading information.

Static interference will only effect NDB transmissions if the receiver is affected by precipitation. In other words the aeroplane must be flying in precipitation to experience static interference.

Thunderstorms can give rise to considerable bearing errors and in the worst case can cause the ADF needle to point to the storm instead of the beacon, as lighting is emitted by the cumulonimbus cloud.

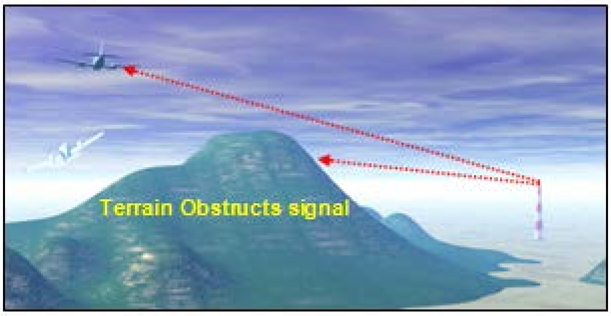
5.5.1.7 Type of Emission

For a given transmission power the range available from a N0N A2A emission is shorter than that available from a N0N A1A emission due to partial transmitter power being used for signal modulation.

Most Australian NDBs are classified as N0N A2A and other N0N A3E, therefor voice (i.e ATIS) can be transmitted together with the Morse code to identify the beacon.

5.5.1.8 Effect of Aircraft Height

NDBs transmit in the LF and MF bands causes radio signals follow the curvature of the earth. Aircraft will be able to receive signals at low level (as long as it is within the rated coverage area). Aircraft height has **no impact** on range of received NDB signals.



Aircraft height will only have an effect on range in mountainous terrain. The errors caused by the reflection and refraction of NDB signals by the terrain may be reduced as the aircraft gains height above the terrain.

Similarly the errors associated with coastal refraction can be reduced by climbing to a higher altitude in order to receive waves that have not been refracted.

5.5.2 Factors Affecting Accuracy

In the discussion on factors affecting range, some of the factors also affected accuracy, and included:

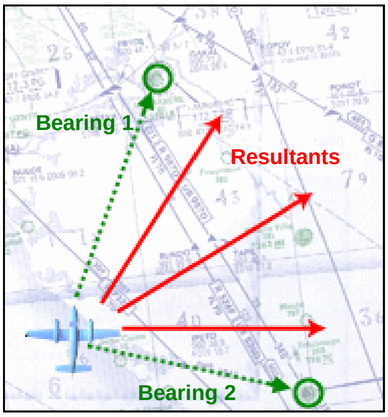
- Night effect
- Type of terrain
- Static

Other factors affecting accuracy which does not necessarily have an effect on range are:

- Station interference
- Quadrantal error
- Loop misalignment
- No failure warning system.

5.5.2.1 Station Interference

More than one NDB in a particular location may be transmitting on the same or similar frequency. This can result in the ADF needle being unable to indicate an accurate bearing.

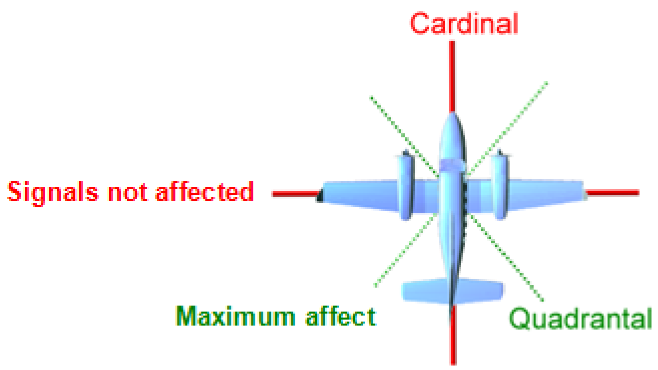


To avoid this error NDBs must not be used beyond their published maximum range.

5.5.2.2 Quadrantal Error

This is caused by incoming signals being reflected and re-radiated from the aircraft fuselage. These signals mix with the signals entering the loop antenna directly from the beacon, causing erroneous indications.

Signals arriving at the loop antenna from the aircraft's relative cardinal points are not affected. Signals arriving at the loop antenna from any other angle are affected.



The maximum effect being when signals arrive from the direction of the aircraft's relative quadrantal points.

These signals are bent towards the aircraft's major electrical axis, which is normally the **longitudinal axis**.

An ADF is regularly calibrated and corrected and with modern equipment this error is negligible.

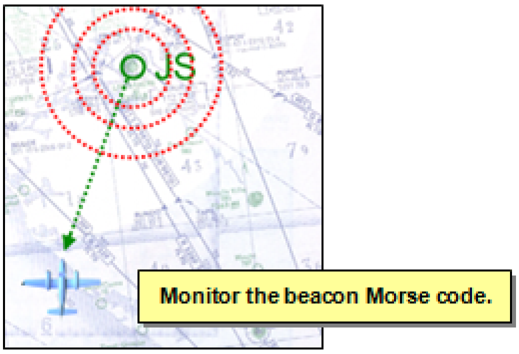
5.5.2.3 Loop Misalignment

If the loop antenna is not exactly aligned with the fore and aft **(longitudinal)** axis of the aircraft, all indicated bearings will be in error by the amount of misalignment. Careful fitting and alignment of the loop will eliminate this error.

5.5.2.4 No Failure Warning System

There is normally no cockpit indication of a ground or airborne equipment failure. This could lead to a hazardous situation with a pilot following erroneous indications. The only way to prevent such a situation in the absence of a built in failure warning device, is to constantly monitor the identification signal (Morse code) and to maintain situational awareness.

This is especially important when flying in poor weather conditions or at night, where the absence of visual cues will make the pilot more reliant on radio navigation aids and internal aircraft navigation systems.



5.5.3 Overall System Accuracy

Considering all the above mentioned factors affecting the range and accuracy of the NDB, it may seem that the system is unreliable and even unsafe to use. That is however not the case.

By being aware of the possible errors and how it can be avoided, the system is reliable and safe to use for radio navigation.

Always use the system within published rated coverage area and continuously monitor the beacon's Morse code transmission. Accuracy of within ±5° for bearings can be expected.

5.6 Calculating Distance and Time to the NDB

A useful technique is to calculate the distance and time to an NDB at any time while receiving the station's signal. The formulae used to calculate the distance and time to an NDB are approximations of the 1-in-60 rule.

The two formulae used are:

$$\text{Time to the NDB} = \frac{60 \times \text{Minutes flown between bearings}}{\text{Degrees of bearing change}}$$

$$\text{Distance to the NDB} = \frac{\text{TAS (or GS)} \times \text{Minutes flown between bearings}}{\text{Degrees of bearing change}}$$

Example

- At 1213 UTC, NDB JS bears 281° relative to the aircraft
- At 1221 UTC, NDB JS bears 263° relative to the aircraft
- TAS = 180 kts
- No wind

If at 1221, the aircraft alters heading to fly direct to JS, what is the distance to go, as well as the ETA to JS?

$$\text{Distance to JS} = \frac{180 \times (1221 - 1213)}{(281° - 263°)} = \frac{180 \times 8}{18°} = 80\text{nm}$$

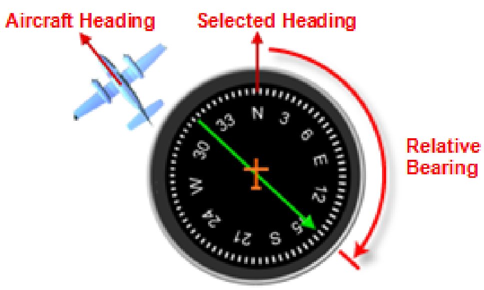
$$\text{Time to JS} = \frac{60 \times (1221 - 1213)}{(281° - 263°)} = \frac{60 \times 8}{18°} = 26.67\text{mins}$$

The distance to go is 80 nm and the ETA will be 1248 UTC.

These formulae are true for all situations, provided the bearings are taken from the same beacon and correct units are used for all values substituted into formulae.

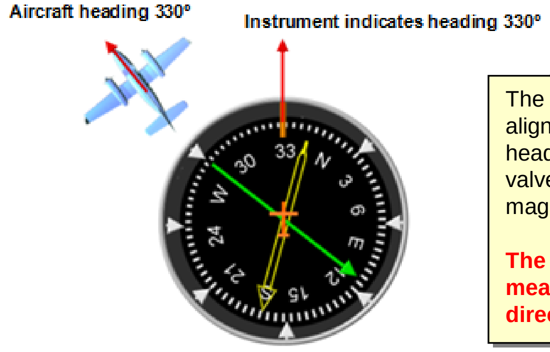
5.7 The NDB - Reading ADF Bearings

The basic method of obtaining a bearing on an NDB is relatively standard, although equipment and facilities may change. The information obtained on the bearing of the aircraft, may be represented in a number of ways, two of which are the Radio Magnetic Indicator (**RMI**) and the Relative Bearing Indicator (**RBI**).



The relative bearing indicator **(RBI)** displays bearings on either a fixed or rotating card display. The fixed card has North or 000° aligned with the nose of the aircraft. The rotating card display allows the crew to manually align the card with the aircraft's heading if so desired.

The relative bearing is the angle measured clockwise from the nose of the aircraft to the direction that the needle is pointing.



The remote magnetic indicator (**RMI**) automatically aligns the card display to the aircraft's magnetic heading. Heading information is supplied via the flux valve. This allows the ADF indication to display the magnetic bearings to and from the station.

The magnetic bearing to the NDB is the angle measured clockwise from Magnetic North to the direction that the needle is pointing.

5.7.1 Types of Bearings

Types of bearings are named by using Q-codes:

- **QUJ** - True track/bearing to the station
- **QTE** - True track/bearing from the station
- **QDM** - Magnetic track/bearing to the station
- **QDR** - Magnetic track/bearing from the station

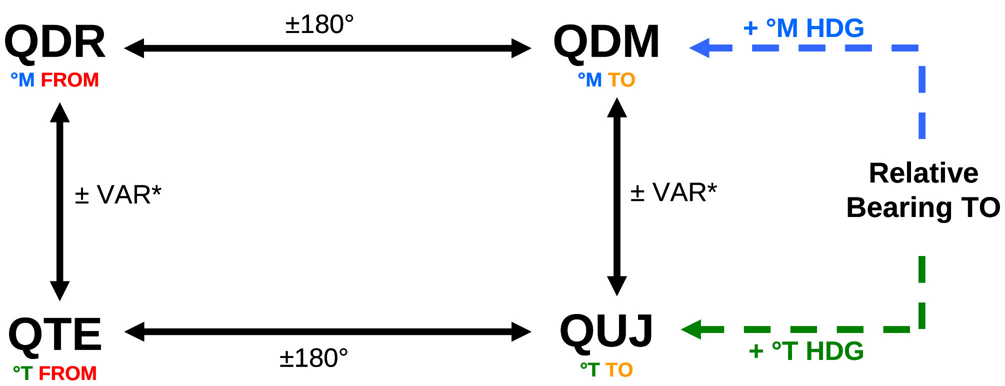
QTE's refer to bearings plotted on a chart. QDM's refer when homing in on a beacon or flying a holding pattern or NDB let down.

5.7.1.1 Relative Bearings

Another bearing type used with the ADF is Relative Bearings and it can be assumed that all relative bearings are obtained from the head of the needle, i.e. the bearing TO the NDB.

It is therefore of the utmost importance that you be able to easily differentiate between the various types of bearings. Refer to NAV1 chapter 5 for revision on the various bearing types and how to convert between them.

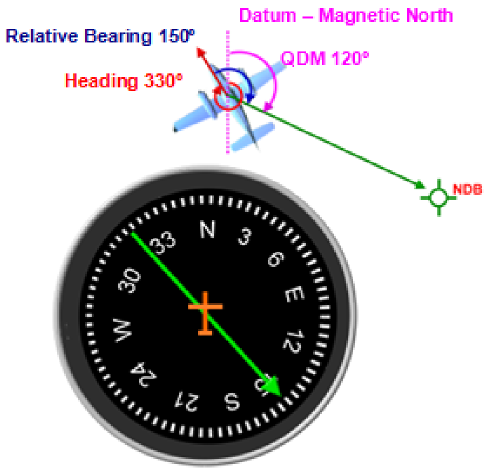
The diagram below illustrates the relationships between the various bearing.



Note that with the NDB the variation at the aircraft's position must be used when converting between true and magnetic bearings, because the direction to the beacon is calculated at the aircraft's position as measured by the ADF system.

5.7.1.2 Determining QDM using the RBI

QDM (**Magnetic Track to the Station**) = Relative Bearing (from the nose of the aircraft to the station) + Aircraft Magnetic Heading.



Example

▪Aircraft Heading 330°M.
▪Relative Bearing TO NDB 150°R.

Therefore: 150°R + 330°M = 480°M (because the value is above 360°, subtract 360°).

480°M – 360° = **120°M as a QDM.**

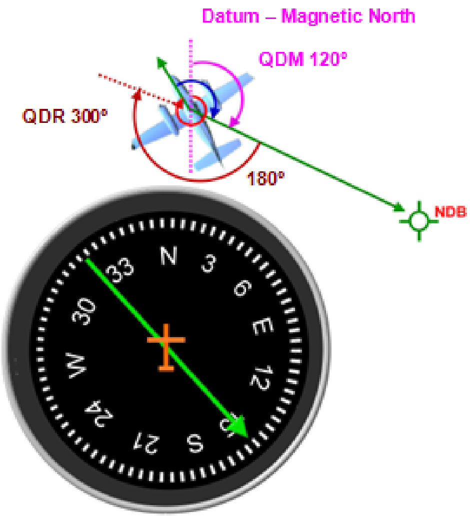
(QDM = Magnetic track to the station).

The magnetic bearing to the NDB (QDM) is useful when requiring the magnetic track to maintain towards the NDB. Apply drift to the track to obtain the magnetic heading to steer for the beacon.

In the example the pilot can alter heading to the right until the needle is pointing 000°R, indicating the aircraft is flying towards the beacon and from which the drift can then be applied.

5.7.1.3 Determining QDR using the RBI

QDR = QDM + 180°



Example

▪Aircraft Heading 330°M.
▪Relative Bearing TO NDB 150°R.

Therefore: 150°R + 330°M = 480°M (because the value is above 360°, subtract 360°).

480°M – 360° = **120°M as a QDM.**

(QDM = Magnetic track to the station)

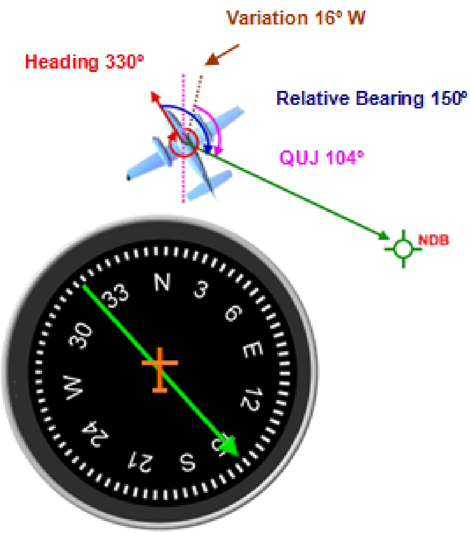
QDR = QDM + 180°
QDR = 120°M + 180°
QDR = 300°M.

(QDR = Magnetic track from the station).

The magnetic bearing from the beacon (QDR) is used to locate the aircraft's position and is used during instrument flying to ensure the aircraft is on the correct track.

5.7.1.4 Determining QUJ using the RBI

QUJ (**True Track to the Station**) = Relative Bearing (**From the nose of the aircraft to the station**) + True Heading (**Magnetic Heading – or + Variation**)



Example

▪Aircraft Heading 330°M.
▪Relative Bearing TO NDB 150°R.

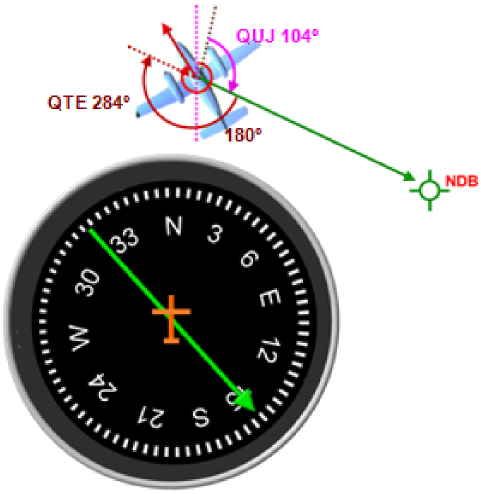
Therefore: 150°R + (330°M –16°W VAR) = 464°T.

464°T – 360° = **104°T as a QUJ.**

(QUJ = True track to the station).

5.7.1.5 Determining QTE using the RBI

QTE = QUJ + 180°



Example

▪Aircraft Heading 330°M.
▪Relative Bearing 150°R.

Therefore: 150°R + (330°M –16°W VAR) = 464°T.

464°T – 360° = **104°T as a QUJ.**

(QUJ = True track to the station).

QTE = QUJ + 180°
QTE = 104°T + 180°
QTE = 284°T.

(QTE = True track from the station).

The true bearing from the beacon (QTE) is used to determine the aircraft's position. By knowing the true bearing, the pilot can plot a position line from the beacon's symbol on the map being valid for that time the bearing was observed.

When two or more position lines are plotted, valid for the same moment in time, the aircraft's position can be determined from the radio fix (intersection of the two position lines).

Radio fixes are only valid under certain conditions, which are mentioned later in this chapter and dealt with in the Command Instrument Rating course.

5.7.2 The RMI and Bearings

The RMI is a repeater from a remote gyro compass system on which radio bearings can be displayed and all displayed bearings will be relative to magnetic north.

ADF bearings are relative bearings measured from the fore / aft axis of the aircraft and since the RMI displays the current heading at the index at the top of the instrument, there is no need for mathematical bearing conversion from degrees relative into degrees magnetic, when using this instrument.

The bearing that is read off at the head of the needle is a **QDM** and the bearing read off at the tail of the needle will be a **QDR**.

Relative bearings can be obtained by finding the angle, measured clockwise, between the heading and the head of the needle pointer.

5.7.2.1 Advantages

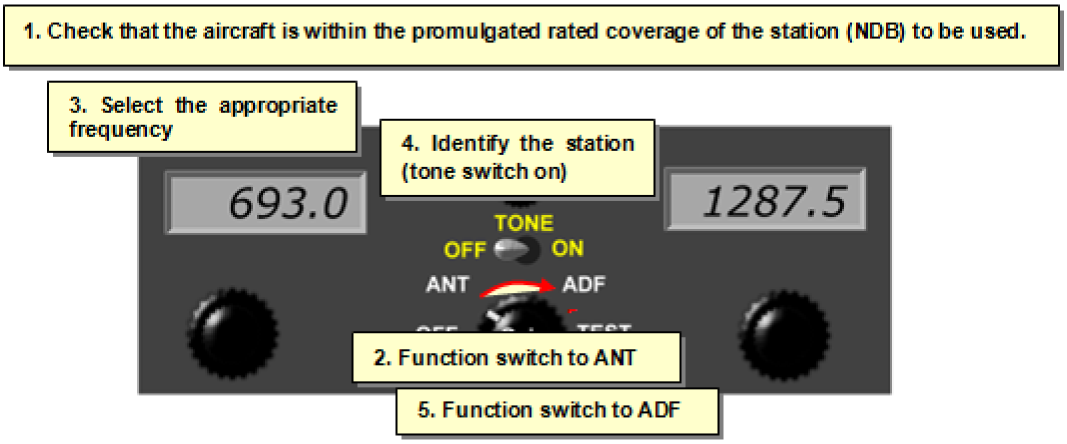
The RMI offers certain advantages over a RBI:

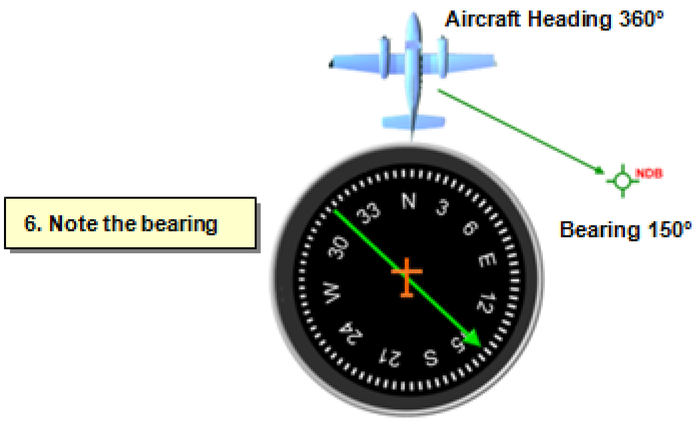
- QDM / QDR are indicated continuously and are read off directly. The head of the arrow indicates the QDM and the tail the QDR.
- Using two beacons, instantaneous fixes can be obtained, by taking simultaneous bearings from the two beacons.
- The indicator can be used for homing to a station or for tracking a specific track away from a station.
- Magnetic heading can be read off together with QDMs on the same instrument.

5.8 Selecting the ADF

The procedure below is a generic operating procedure for using the ADF system. Refer to your aircraft manual for more specific instructions as variations in style or design of cockpit controllers exist.

The following procedure is used for the ADF:





5.8.1 Rated Coverage and Broadcasting Information

Before using the ADF indications, the pilot must verify that the aircraft is within the rated coverage for the particular beacon being used.

The likelihood of experiencing many of the errors associated with NDB range and accuracy is reduced when using the beacon that is within the rated coverage.

Rated coverage information is available in both the ERSA FAC section (listed per aerodrome) and in the Jeppesen Radio Aids section, from page AU37 onwards. The extract included below is from the Jeppesen:

This listing provides only those navaids (VOR, DME, TACAN, NDB) where range and/or navaid limitations are applicable. Navaids are sequenced by their official names. City names are included in parentheses when different than the navaid name. Distances are nautical miles. Bearings and radials are from the navaid.

LOCATION IDENT	NAVAID	LIMITATIONS
Albany, WA		
ABA	NDB	Range: 100HJ/60HN, over water 200HJ/110HN.
Albury, NSW		
AY	NDB	Range: 65
Alice Springs, NT		
AS	NDB	Range: 110HJ/90HN
Amberley, QLD		
AMB	NDB	Range: 180HJ/85HN
Andamooka, SA		
AMK	NDB	Range: 45
Archerfield (Brisbane), **QLD**		
AF	NDB	Range: 30, excessive bearing fluctuations between 180° - 200°.
Armidale, NSW		
ARM	NDB	Range: 35
Ayers Rock, NT		
AYE	NDB	Range: 100
Bagot (Darwin), **NT**		
BGT	NDB	Range: 50
Bairnsdale, VIC		
BNS	NDB	Range: 35
Balgo Hill, WA		
BGO	NDB	Range: 70
Ballarat, VIC		
BLT	NDB	Range: 30

The table represent both land and water ranges for NDBs by day (HJ) and night (HN), in addition to other navaids with range or coverage restrictions.

5.8.1.1 Using the NDB for Position Fixes

The rules for using NDB bearings during flight to determine the aircraft's position can be found in the AIP as well as in the Jeppesen Air Traffic Control section, on page AU507 par 5.5.

These rules need to be observed when plotting NDB position lines for position fixing purposes or when intending to use the indications of station passage as a method of establishing a radio fix.

5.8.2 NDB Information Available on Charts

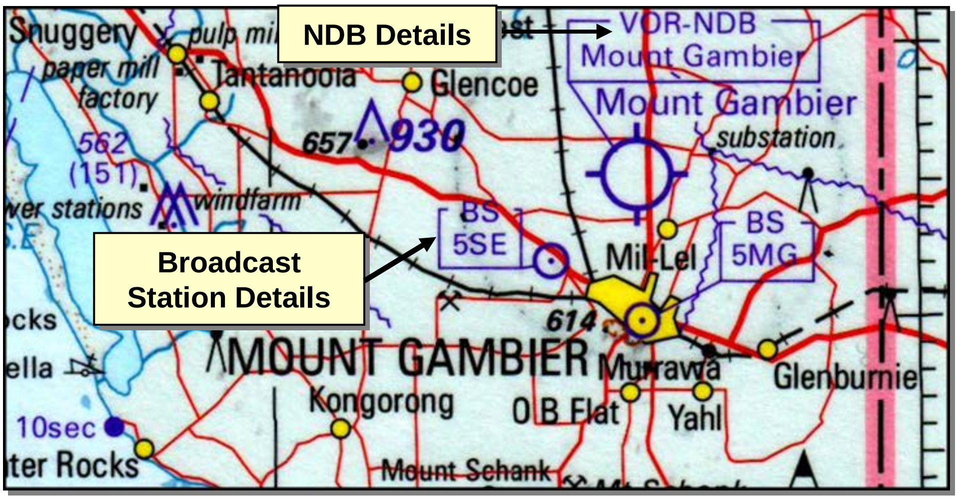
Limited information regarding NDBs can be obtained from the various aeronautical maps and charts available in Australia.

The amount of information available varies between charts, with the WAC having the least information, the VNC and VTC having slightly more information and the en-route radio navigation charts from the Jeppesen or Airservices (ERC) having the most information.

5.8.2.1 NDB Information on the WAC

Very little information is shown on the WAC regarding the NDB. Below it can be observed that there is a NDB located at the Mount Gambier aerodrome and the chart does not show the frequency or ICAO identifier of the beacon.

The WAC also uses a single symbol for any radio beacon type, an example of which is shown at the position of the broadcast station "5SE".

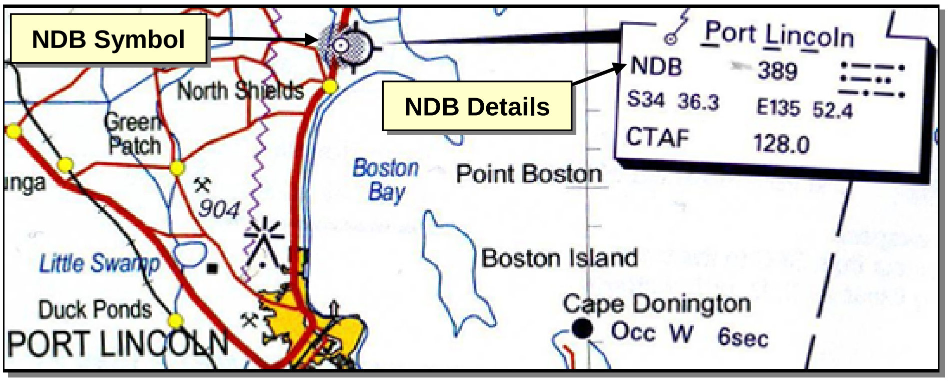


5.8.2.2 NDB Information on the VNC

The VNC has a special symbol used for the NDB, which conforms to the ICAO standard set of symbols. A text box next to the beacon depicts the following:

- ICAO Identifier – PLC (underlined letters of **P**ort **L**in**c**oln)

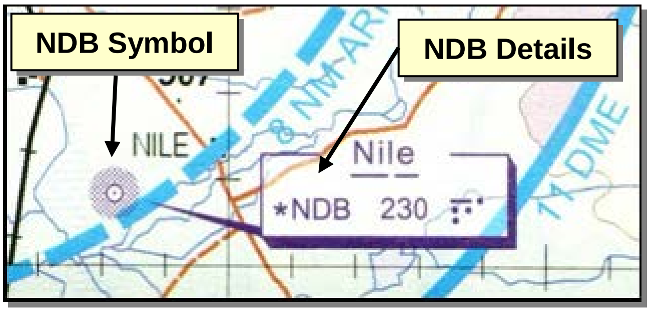
- Frequency – 389 kHz
- Morse Code decode for PLC



5.8.2.3 NDB Information on the VTC

The level of information shown on the VTC is similar to the VNC and the layout is similar depicting:

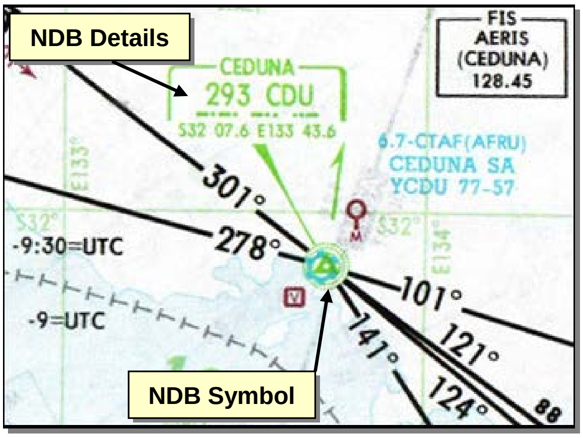
- ICAO Identifier – NIE (underlined letters of **Nile**)
- Frequency – 230 kHz
- Morse Code decode for NIE
- The asterisk(*) denotes that the beacon has limited functionality – see Jeppesen Radio Aids page AU41.



5.8.2.4 NDB Information on the Jeppesen En-route Charts

The highest level of beacon related information can be found on the en-route charts. The ICAO symbol is used for the NDB. A text box next to the beacon depicts the following:

- Plain language name of the NDB - Ceduna
- ICAO Identifier – CDU
- Frequency – 293 kHz
- Morse Code decode for CDU
- Coordinates of the NDB


NDB Details
CEDUNA
293 CDU
S32 07.6 E133 43.6
FIS
AERIS
(CEDUNA)
128.45
6.7-CTAF(AFRU)
CEDUNA SA
YCDU 77-57
301°
278°
101°
121°
124°
141°
-9:30=UTC
-9=UTC
NDB Symbol

5.9 Worksheet – Automatic Direction Finding

1. ADF uses NDB or AM broadcast stations which transmit in the:
   a. VLF and LF bands
   b. LF and MF bands
   c. MF and HF bands
   d. HF and VHF bands.

2. The principle of operation of the ADF can be described as:
   a. Radar ranging
   b. Phase comparison
   c. Loop theory
   d. Timing of signals.

3. The shape of the polar diagram of the NDB can be described as:
   a. A cardioid
   b. A limacon
   c. Omni-directional
   d. A figure of eight.

4. Which statement is true regarding the principle of operation of a NDB?
   a. The maximum signal strength position is used for direction reference.
   b. The null position is used for direction reference.
   c. The sense antenna has a 180° ambiguity.
   d. The phase difference between signals relates directly to bearing to the NDB.

5. Which one of the following statements regarding range and accuracy of the NDB is correct?
   a. The bearing error caused by Night Effect is at its worst at midnight.
   b. Coastal refraction is greater the further inland a coastal NDB is located.
   c. If transmission power is doubled the range can be increased four times.
   d. Climbing to a higher altitude will allow for greater NDB reception range.

6. An aircraft is heading 030°T and variation is 12°E. What is the bearing to the NDB if the relative bearing to the station is 295°R?

    a. 337°M

    b. 313°T

    c. 325°T

    d. 295°M.

7. An aircraft is heading 275°M with variation of 5°E. What is the bearing from the NDB if the relative bearing to the station is 295°R?

    a. 300°T

    b. 215°M

    c. 210°M

    d. 030°M.

8. What is the rated coverage of the NDB at Port Lincoln, over water, by day?

    a. 70 nm

    b. 85 nm

    c. Maximum range depends on aircraft altitude

    d. 140 nm, since range over water is further than range over land.

5.9.1 Worksheet Answers

1B	2C	3A	4B
5B	6C	7D	8B