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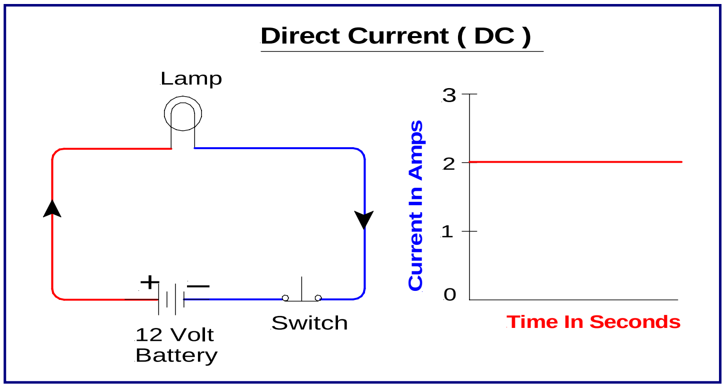
CHAPTER 1

Basic Radio Theory

Direct Current

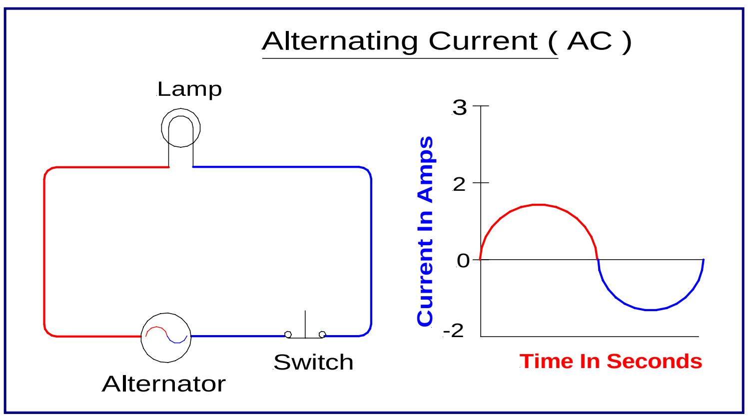
Current is defined as to how much power a circuit has. Direct current is the flow of current in one direction only. DC or Direct Current is normally used in the power supplies of aircraft.

DC or Direct Current cannot be used in the transmission of radio energy because there is no change in direction and thus no radiation properties.



Alternating Current

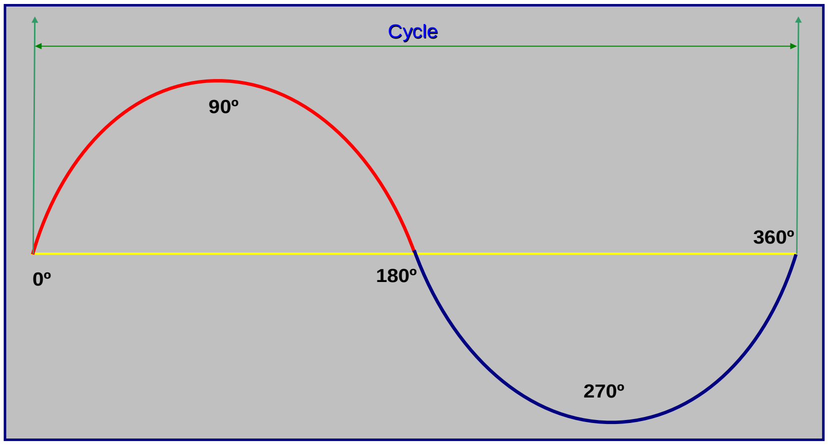
Alternating Current or AC is the flow of current in opposite directions. The current reverses its direction a number of times a second. Alternating Current or AC can be used in the transmission of radio energy because of this change in direction and thus the radiation properties. Alternating Current or AC radiates away from the source in the form of Electromagnetic Waves. Alternating Current is also used in AC power supplies.



Radio Wave Definitions

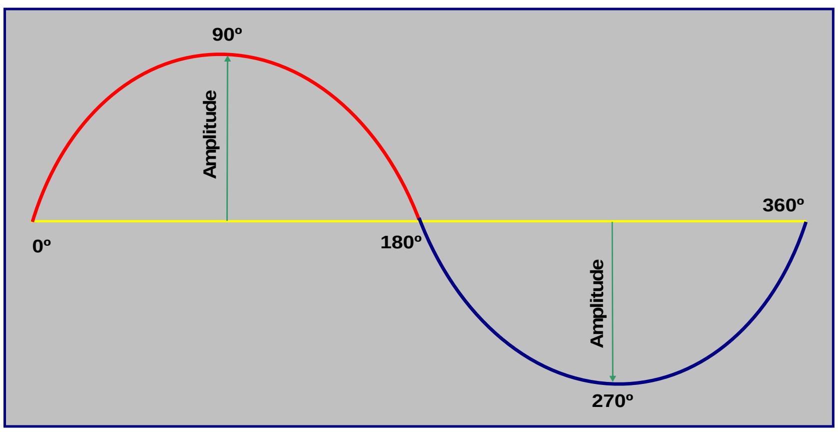
Cycle

The cycle may be defined as a complete series of values i.e. from zero to max positive then to zero then to max negative and then back to zero. It may also be defined as a complete change of direction of flow.



Amplitude

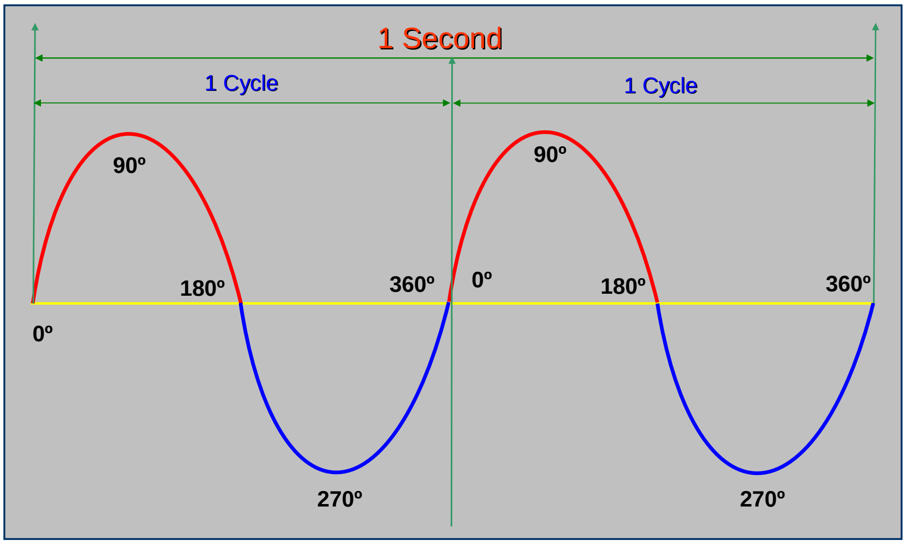
Amplitude may be defined as the maximum or peak displacement in a positive or negative value attained, from the mean reference during a complete cycle. Amplitude is normally expressed in Volts (V) or Amperes (A).



Radio Wave Definitions

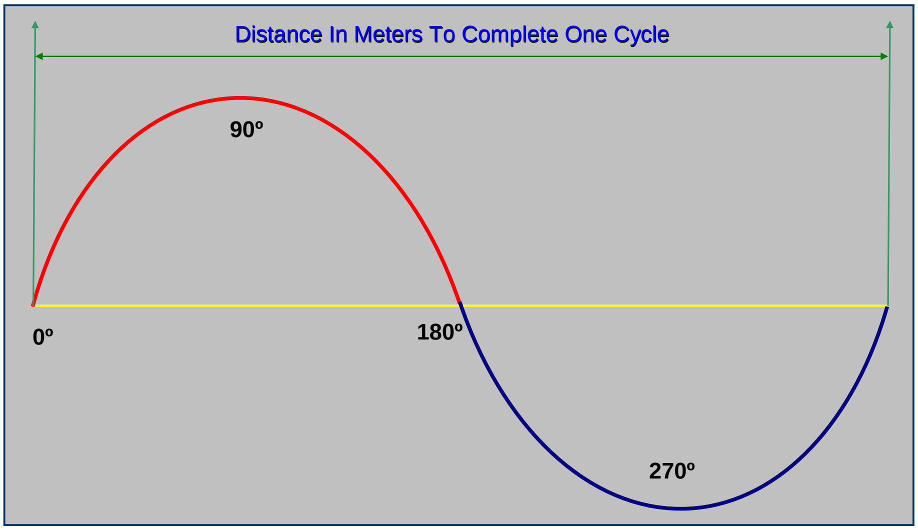
Frequency

Frequency may be defined as the number of complete cycles in one second. Frequency is always expressed in cycles per second or Hertz (Hz). Frequency is always referenced to time i.e. cycles per second.



Wavelength

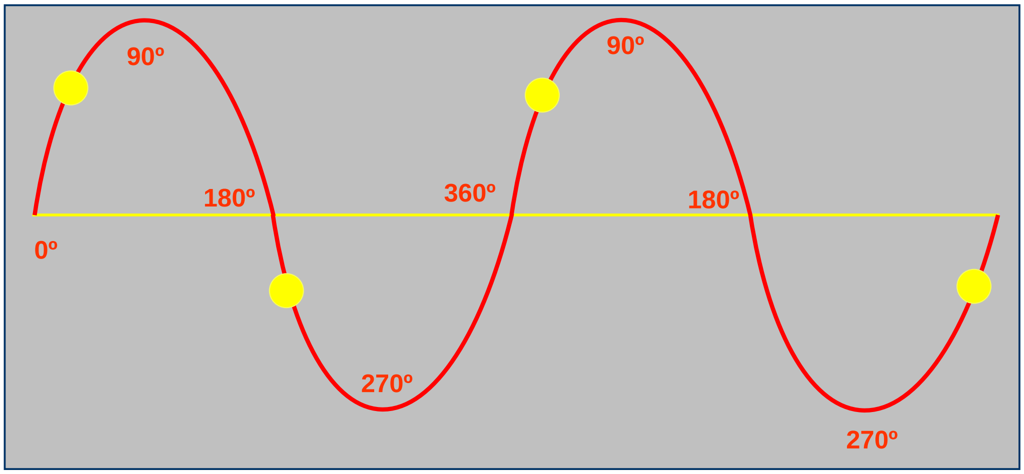
Wavelength may be defined as the distance travelled during one cycle. Wavelength is always expressed in meters (m). Wavelength is always referenced to distance i.e. meters. Wavelength must be measured over a full or complete cycle.



Phase and Phase Difference

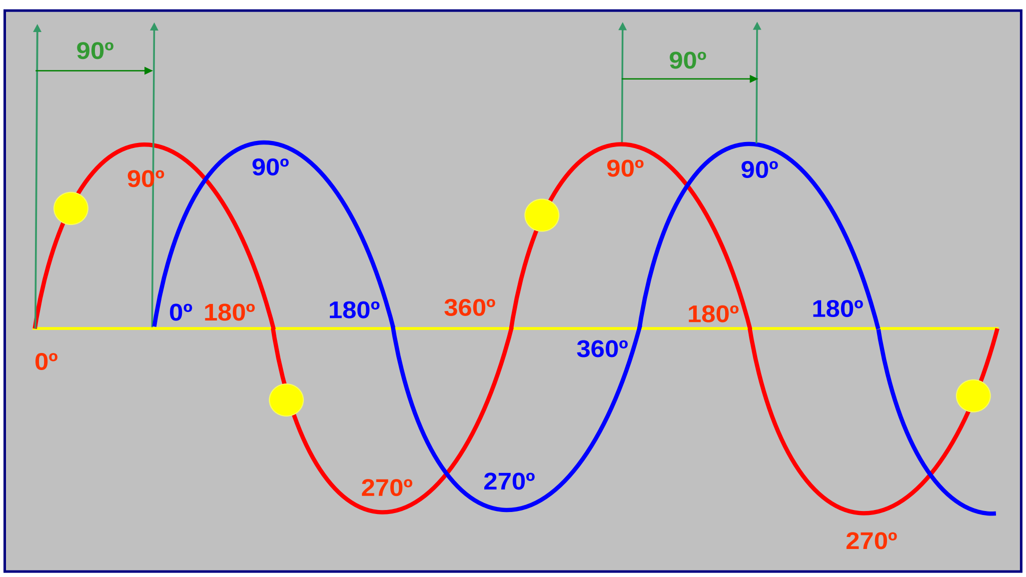
Phase

Phase may be defined as a particular point in a cycle. The phase of the wave can vary from zero degrees (0º) to three hundred and fifty nine degrees (359º) in one complete cycle.



Phase Difference

Phase difference may be defined as the angular difference between two radio waves. Radio waves can be in phase if the two waves are aligned and out of phase if the two waves are not aligned. Phase difference is always expressed in degrees. To measure the phase difference between two radio waves they must have the same frequency and the point of measurement must be the same in both waves.



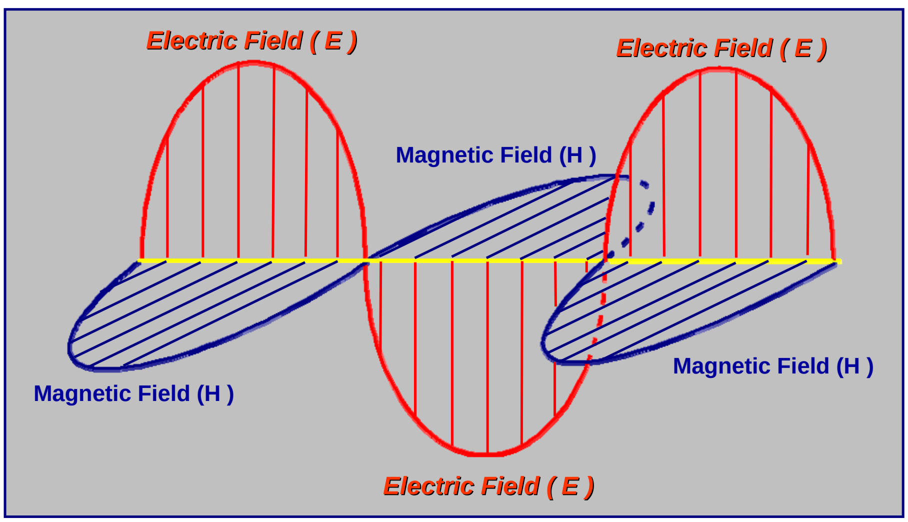
Sound Waves and Radio Waves

Sound Waves

- Sound waves are in the human hearing range and are between 50 Hz and 15 KHz.
- Sound waves need a medium to travel through i.e. atmosphere, solid or liquid.
- Sound waves travel by vibrating the molecules of the medium like a knock-on effect.
- Sound waves cannot be transmitted very far because of the power required e.g. a megaphone.
- Sound waves travel at the speed of sound, which is roughly 1200 kilometres per hour.

Radio Waves

- Radio waves are outside the human hearing range and cannot be heard.
- Radio waves do not need a medium to travel through; they can travel through space.
- Radio waves travel in the form of an electromagnetic wave.
- Radio waves can easily be transmitted over great distances using radio transmission.
- Radio waves travel at the speed of light which is 300 000 000 meters per second.



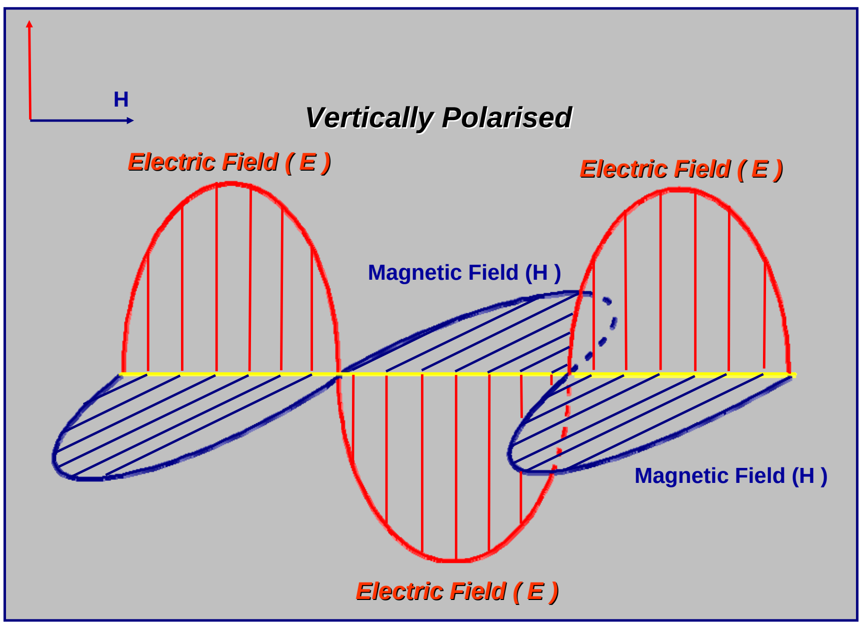
Polarisation

Electromagnetic energy is radiated as a wave. This wave consists of a combination of electric and magnetic fields. These fields are at right angles to each other and at right angles to the direction of propagation. Polarisation may be defined as the plane of oscillation of the electrical field of an electromagnetic wave.

If a transmitter has a vertical aerial it produces a vertically polarised wave i.e. the electrical field is in the vertical plane and the magnetic field is in the horizontal plane. If a transmitter has a horizontal aerial it produces a horizontally polarised wave i.e. the electrical field is in the horizontal plane and the magnetic field is in the vertical plane. In general a vertically polarised wave will achieve a better range at frequencies up to and including VHF band and a horizontally polarised wave will achieve a better range at UHF band and above.

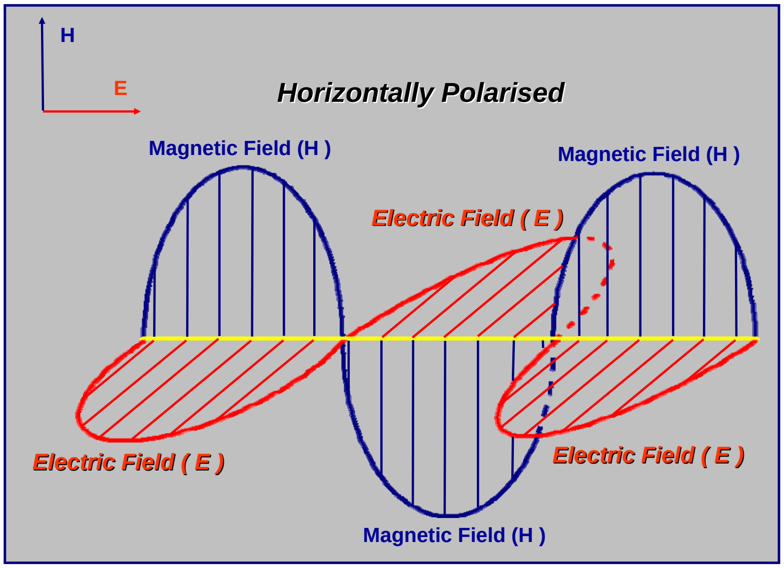
Vertically Polarised Radio Waves

Electromagnetic waves which have an electrical field in the vertical plane and a magnetic field in the horizontal plane.



Horizontally Polarised Radio Waves

Electromagnetic waves which have an electrical field in the horizontal plane and a magnetic field in the vertical plane.



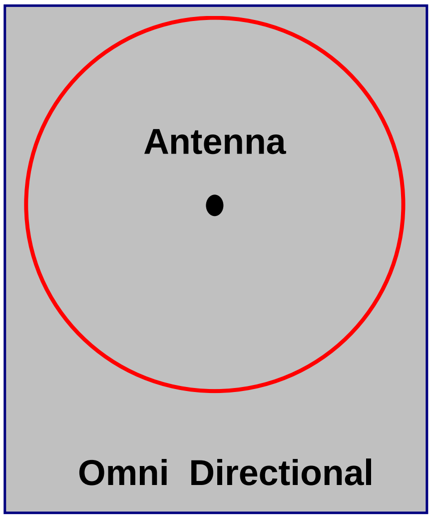
Polar Diagrams

A polar diagram is a representation of the radiation pattern of an aerial. The distance from the point of origin to the outer edge represents the distance at which a signal of the same strength is received.

There are two types of polar diagrams that will be discussed namely, Directional Polar Diagrams and Omni-Directional Polar Diagrams.

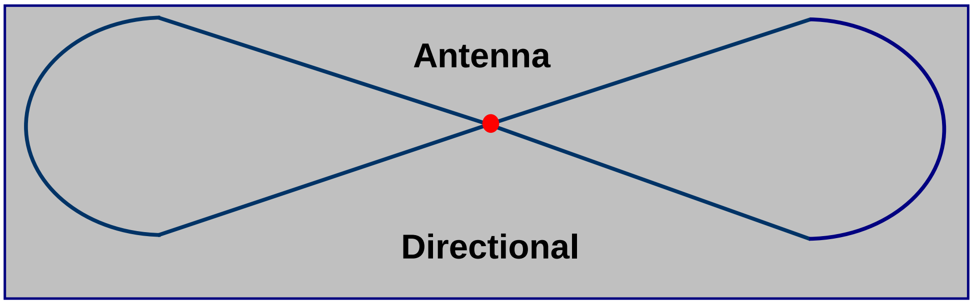
Omni-Directional Aerial

Omni-Directional Aerials transmit radio waves equally in all directions. This type of aerial is used when the radio wave has to be received from any direction i.e. an ADF radio.



Directional Aerial

Directional aerials transmit radio waves in a specific direction. This type of aerial is used when the radio wave has to be received in a specific direction i.e. an ILS radio.



Frequency Spectrum

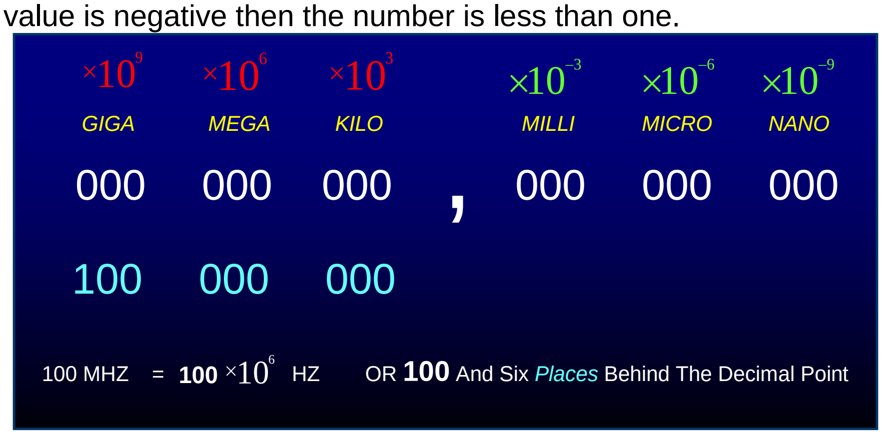
Frequencies used in radio transmissions are divided into different bands, each having its own characteristics.

Frequency Band	Frequency	Type of Propagation	Uses
VLF – Very Low Frequency	3 – 30 KHz	Ground Wave	Long range communication and navigation, e.g. Omega
LF – Low Frequency	30 – 300 KHz	Ground & Sky Wave	Medium range communication and navigation, e.g. Decca
MF – Medium Frequency	300 – 3000 KHz	Ground & Sky Wave (200nm for ground wave and thousands of miles for sky wave)	NDB 
HF – High Frequency	3 – 30 MHz	Sky Wave	Communication 

VHF – Very High Frequency	30 – 300 MHz	Direct Wave	Communication, VOR, ILS Localiser 
UHF – Ultra High Frequency	300 – 3000 MHz	Direct Wave	DME, ILS Glide Slope 
SHF – Super High Frequency	3 – 30 GHz	Direct Wave	Weather Radar, Doppler navigation aids 
EHF – Extra High Frequency	30 – 300 GHz	Direct Wave	Mainly experimental

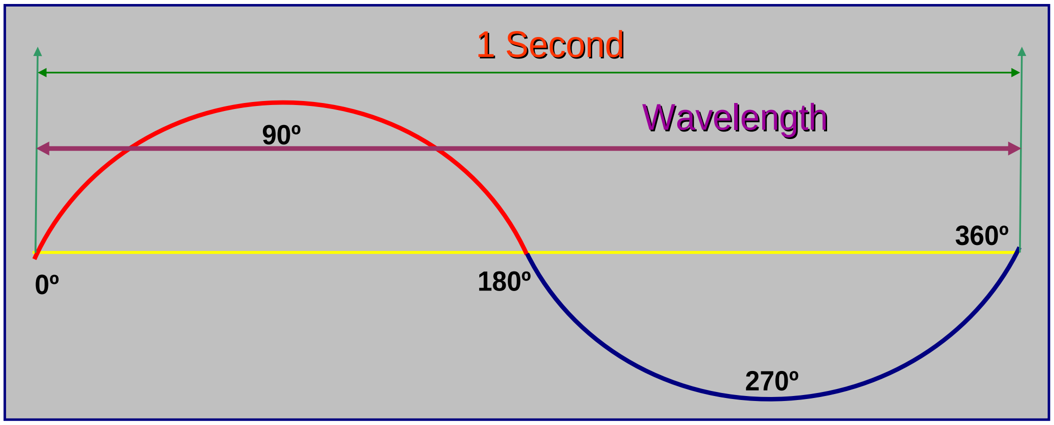
Exponents Exp

We use the Exponent (Exp) function on the calculator to simplify the calculation when working with very large or small numbers. The exponent value indicates the number of places left or right of the decimal point. If the exponent value is positive then the number is greater than one; if the exponent value is negative then the number is less than one.

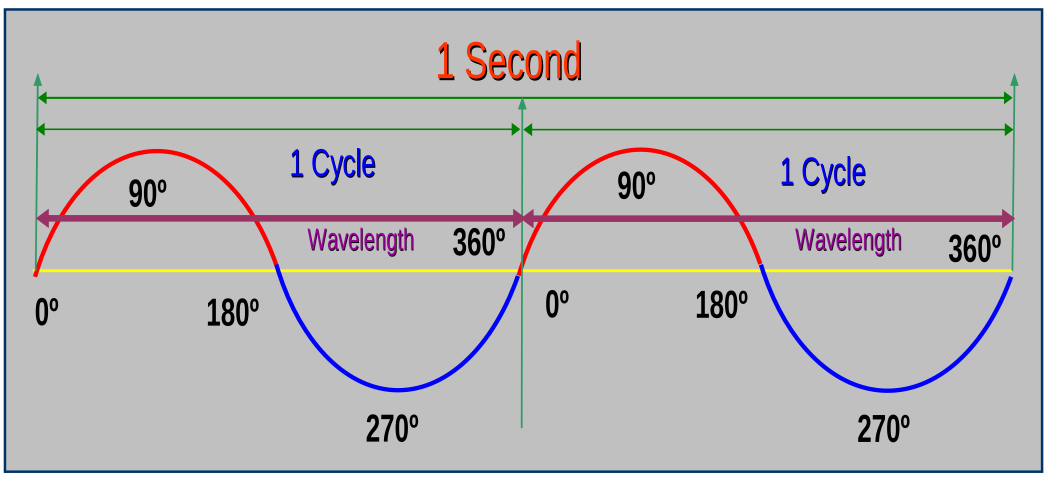


Relation between Frequency and Wavelength

Frequency is always expressed in cycles per one second and wavelength in meters. If we consider the frequency wavelength relationship it must be noted that the higher the frequency the more cycles per second there are. As the speed of a radio wave is constant and the time of one second is constant then to have a higher number of cycles in a constant time and distance the wavelength must decrease and visa versa. As the frequency increases the wavelength must get shorter and as the frequency decreases the wavelength must get longer.



Low frequency has less number of cycles per second and a long wavelength.



High frequency has more number of cycles per second and a shorter wavelength.

Wavelength Frequency Relationship Calculations

Wavelength Frequency Calculations are solved using the formula below. When doing the calculations it must be noted that it is important to make sure that all the values are in their correct units i.e. wavelength is in meters, frequency is in cycles per second or Hz and that the speed of light is in meters per second.

$$\lambda = \frac{C}{F}$$

λ = Wavelength In *Meters*

C = Speed Of Light In *Meters / Second*

F = Frequency In *Cycles / Second* Or Hz

Example No 1

What is the wavelength of an ILS transmitting on a frequency 108.1 MHz?

$$\lambda = \frac{C}{F}$$

$$\lambda = \frac{3 \times 10^8 \text{ Meters / second}}{108.1 \times 10^6 \text{ Cycles / second}}$$

$$= \mathbf{2.777 \text{ Meters}}$$

Example No 2

What is the frequency corresponding to a wavelength of 0.4 Kilometre?

$$\lambda = \frac{C}{F}$$

$$400 \text{ Meters} = \frac{3 \times 10^8 \text{ Meters / second}}{\text{Frequency} \quad \text{Cycles / second}}$$

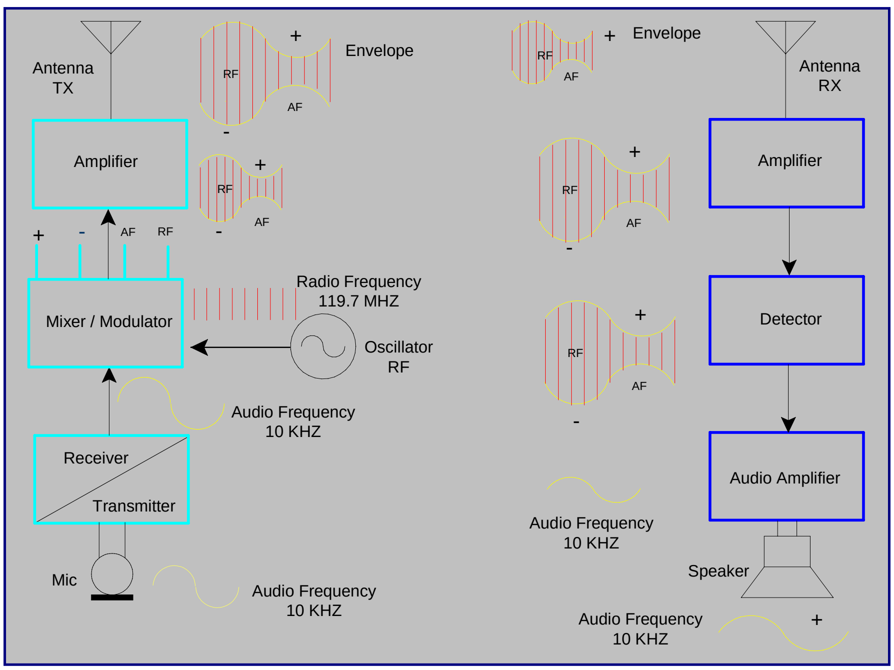
$$\text{Frequency} = \frac{3 \times 10^8 \text{ Meters / second}}{400 \text{ Meters}}$$

= 750 000 HZ OR **750 KHZ**

Basic Radio Theory and Radio Transmission

This diagram is a graphical representation of the location of the components of a basic radio system. As we can see audio is transmitted by the pilot through the microphone in the aircraft. The microphone converts this sound wave into an electrical wave for the transmitter (TX) to use. The electrical signal is then sent to the modulator where it is mixed with the radio wave from the oscillator (BFO); this is called modulation. The radio wave is sent to an amplifier where it is amplified and finally transmitted from the transmitter antenna to the receiver antenna; this transmission of radio waves is called propagation of the radio waves.

The radio wave is received by the receiver antenna and sent to the radio frequency amplifier (RF Amp) where it is amplified for use in the receiver. The next stage is the detector where the radio wave is decoded to remove the information off the carrier wave; it is then amplified and sent to a speaker where the information is heard.



Modulation

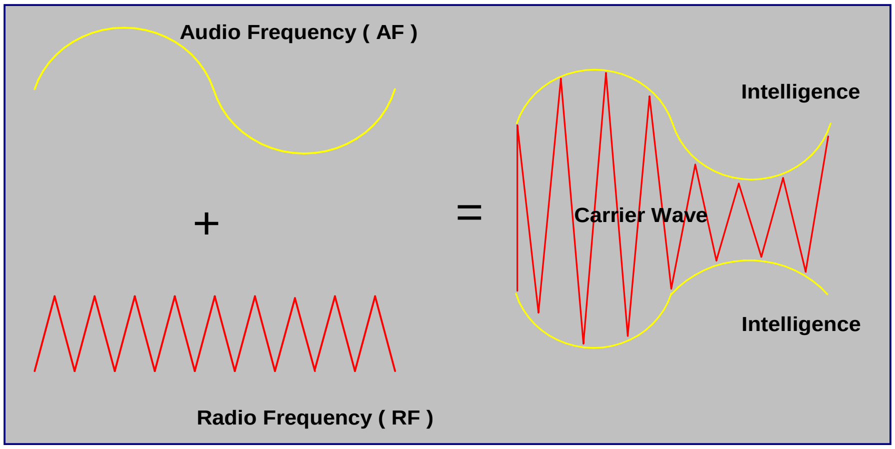
Sound waves can be heard but cannot be transmitted whereas radio waves can be transmitted but not heard. We thus need a method to transmit information over long distances and at high speed. Modulation is the process of superimposing information or intelligence onto a radio wave so that it can be transmitted by means of radio wave propagation.

There are two types of modulation that will be discussed in the Commercial Radio syllabus.

- **Amplitude Modulation**
- **Frequency Modulation**

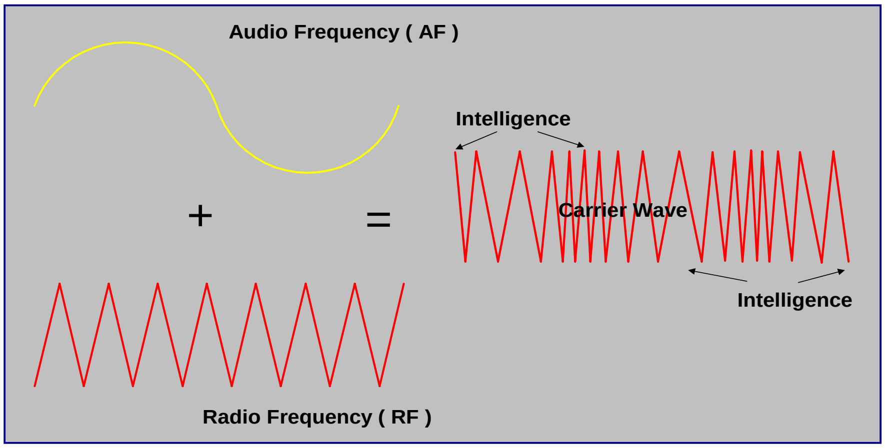
Amplitude Modulation

Radio waves are said to be Amplitude Modulated when the amplitude of the radio wave varies in accordance with the information, but the frequency remains constant.



Frequency Modulation

Radio waves are said to be Frequency Modulated when the frequency of the radio wave varies in accordance with the information, but the amplitude remains constant.



Depth of Modulation

Depth of Modulation may be defined as the extent to which the carrier is modulated and is expressed as a percentage. Modulation is kept to just below one hundred percent to prevent distortion of the signal. An un-modulated signal has a longer range than a modulated signal.

Example No 1

What is the depth of modulation of the following radio wave if the amplitude of the audio signal is 10 Volts and the amplitude of the carrier signal is 15 Volts?

$$\frac{\text{Peak Amplitude Of The } \textbf{Audio} \text{ Signal}}{\text{Peak Amplitude Of The } \textbf{Carrier} \text{ Signal}} \times 100$$

$$\frac{10 \text{ Volts}}{15 \text{ Volts}} \times 100$$

$$= \mathbf{66.667\ \%}$$

Sidebands

Sidebands are additional frequencies that are produced when a carrier frequency is Amplitude Modulated by a frequency lower than itself. Four frequencies are produced, these are:

- The original carrier frequency
- The original audio frequency
- The addition frequency
- The subtraction frequency

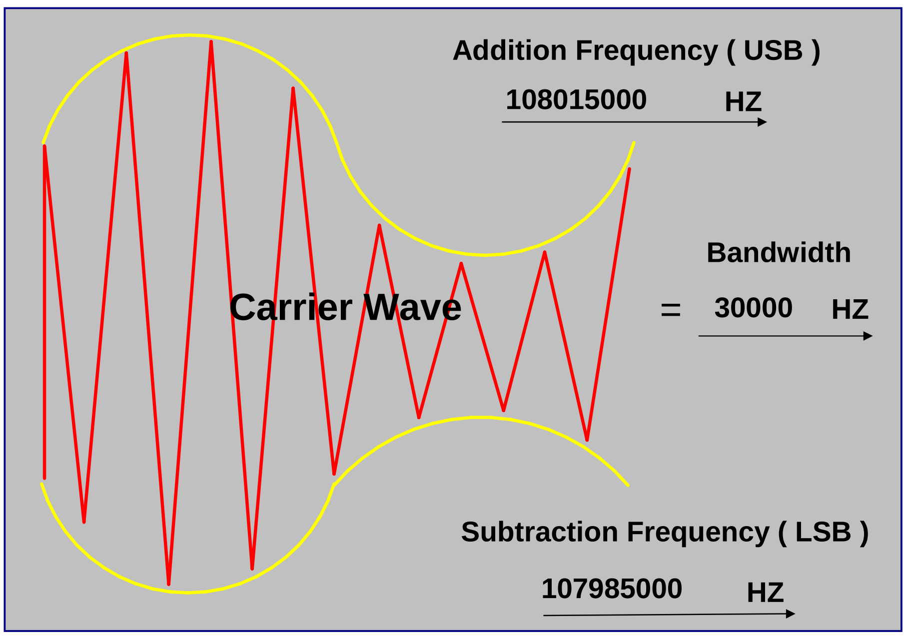
The distance between the addition frequencies i.e. the upper sideband and the subtraction frequencies i.e. the lower sideband is called the bandwidth. Note that the signal strength reduces toward the sidebands.

Sideband Calculation

What is the bandwidth of the following Amplitude Modulation: The carrier frequency is transmitting on 108.1 MHz and is amplitude modulated by an audio frequency of 15 KHz?

Carrier Frequency	=	108	x	10^{6}	Hz
Audio Frequency	=	15	x	10^{3}	Hz
Addition Frequency	=	108015000		Hz	
Subtraction Frequency	=	107985000		Hz	
Bandwidth	=	**30000**	**Hz**	**Or**	**30 KHz**

Sideband Graphic

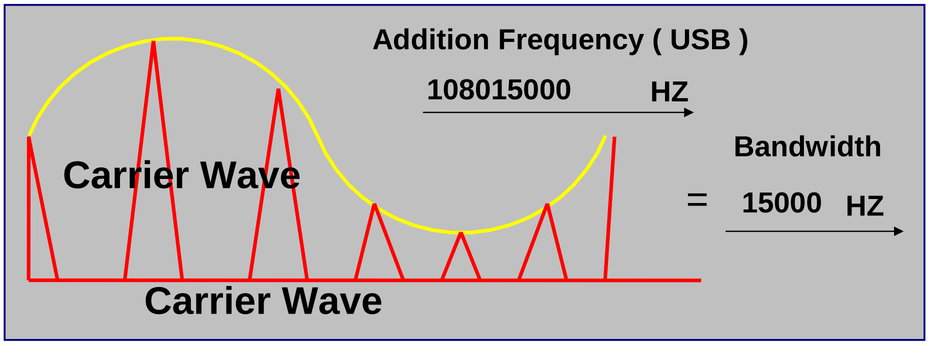


Single Sideband Transmission

Two thirds of the power of an Amplitude Modulated signal is used to generate the carrier wave and only one third is required to generate the modulation. The information or intelligence is contained in the two bands either side of the carrier frequency known as the upper sideband and the lower sideband.

The two sidebands are mirror images of each other so one of them is suppressed without losing any information. It is also possible to suppress the carrier wave therefore only to transmit the single sideband. The carrier frequency must be reintroduced at the receiver to decode the information.

The advantage of single sideband transmission is to reduce the bandwidth, allowing more channels to be used without any interference between them. By transmitting a narrower bandwidth it increases the range for the same amount of transmitting power.



Designation of Emissions for Navigation Aids and Communication

The designation of emissions gives information on bandwidth and class of emission. Bandwidth is expressed by three numerals and one letter. The letter shows where the decimal point is located and also its unit of bandwidth.

Example

400 Hz	=	400H
1200 Hz	=	1K20
3.3 KHz	=	3K30
4 MHz	=	4M00
18.4 KHz	=	18K4

Class of Emissions

The class of emissions are given by three characters e.g A1A, A9W. The first symbol indicates the type of modulation of the carrier wave, the second symbol indicates the nature of the modulating signal and the third symbol indicates the type of information to be transmitted. The following examples are important:

- ILS A2A
- VOR A9W
- NDB A1A or A2A
- TACAN MID
- TRANSPONDER MID
- VHF Communications A3E
- HF Communications J3E

Rules for Radio Wave Propagation

Attenuation

Attenuation may be defined as the reduction in signal strength of a radio wave as it travels away from the transmitter. Signal strength is inversely proportional to the square of the distance from the transmitter. To double the range of a radio wave the power must be increased by four times. As a rule the higher the frequency the greater the attenuation.

Refraction

Refraction may be defined as the change of direction of a radio wave as it passes from one medium to another. Radio waves will refract toward the denser medium. As a rule the higher the frequency the less the refraction.

Diffraction

Diffraction may be defined as the change of direction of a radio wave as it passes over the earth. As a rule the higher the frequency the less the diffraction.

Range

The range of a radio wave depends on the transmitter power, the frequency and the type of antenna used. As a rule the higher the frequency the shorter the range.

Critical Angle

Critical angle is the design angle at which the radio wave leaves the transmitter antenna. As a rule the higher the frequency the greater the critical angle.

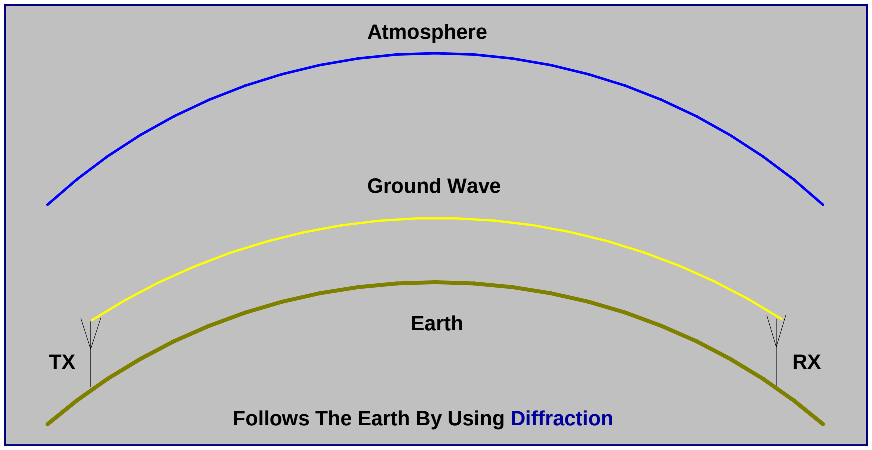
Classification of Radio Waves

Radio waves can be classified into three types:

- Ground waves
- Direct waves
- Sky waves

Ground Waves

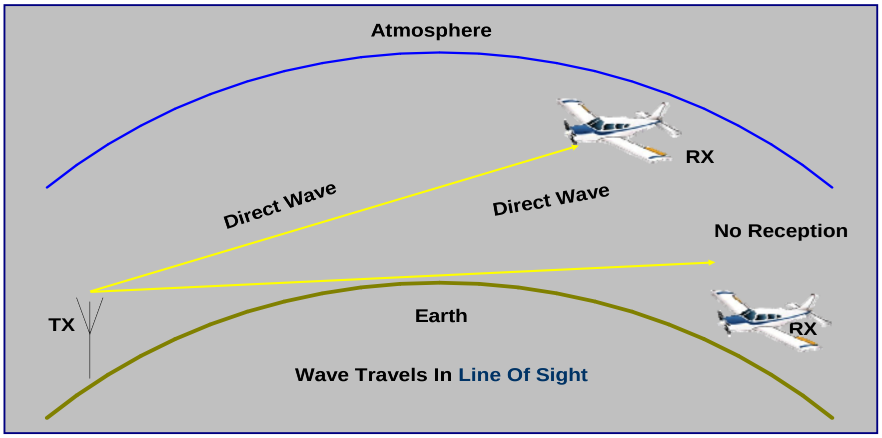
Ground waves follow the surface of the earth by means of diffraction and are predominantly in the VLF and LF and partially in the HF radio frequency bands. Ground waves have a very long range up to 12000 Nm but have very high noise levels. This type of frequency was used in the Omega long-range navigation system but was costly to produce because of the large amounts of power required, and the large antenna arrays that were needed to transmit the wave.



Direct Waves

Direct waves travel in straight lines and have no over-the-horizon capability. Direct waves are found in the VHF radio frequency band and higher. The transmitter and receiver must be able to see each other i.e. line of sight. The range of a direct wave is approximately 200 Nm as the higher the frequency the shorter the range.

Direct Waves



Maximum Theoretical Range

The maximum range of a direct radio wave is also limited by the curvature of the earth. If the transmitter and receiver are too far apart they will not be able to see each other because either the transmitter or receiver is below the horizon. The maximum theoretical range can be calculated by the following formula:

$$\text{Range (NM)} = 1.25 \times \sqrt{Tx \text{ Height In } \boldsymbol{FEET}} + 1.25 \times \sqrt{\text{RX Height In } \boldsymbol{FEET}}$$

Maximum Theoretical Range Calculation

If an aircraft is at Fl 100 what is the maximum theoretical range that the signal can be received from a transmitter at 100 feet?

$$\text{Range (NM)} = 1.25 \times \sqrt{\text{RX Height In } \boldsymbol{FEET}} + 1.25 \times \sqrt{Tx \text{ Height In } \boldsymbol{FEET}}$$

$$\text{Range (NM)} = 1.25 \times \sqrt{10\,000 \textit{ Feet}} + 1.25 \times \sqrt{100 \textit{ Feet}}$$

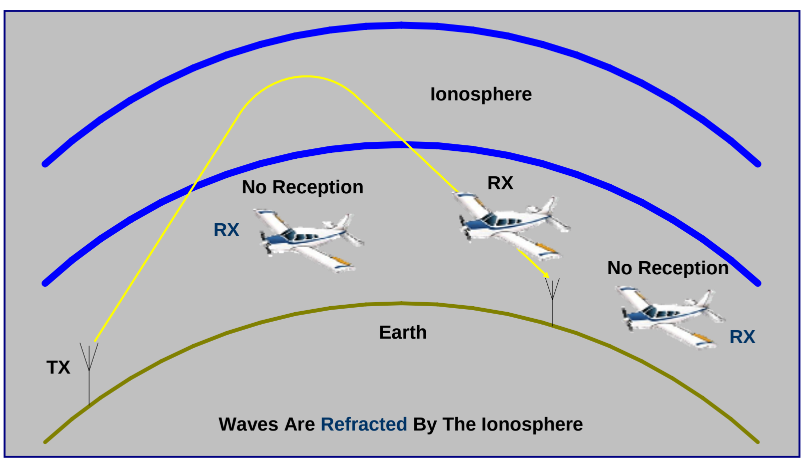
$$\text{Range (NM)} = 1.25 \times 100 + 1.25 \times 10$$

$$\text{Range (NM)} = 125 + 12.5$$

$$\text{Range (NM)} = 137.5 \text{ NM}$$

Sky Waves

Sky waves are radio waves, which have been refracted by the ionosphere. Sky waves are used in long-range communication such as HF communication. As the radio wave travels from the antenna it enters the Ionosphere and slows down, this causes the radio wave to bend or refract back to the earth.

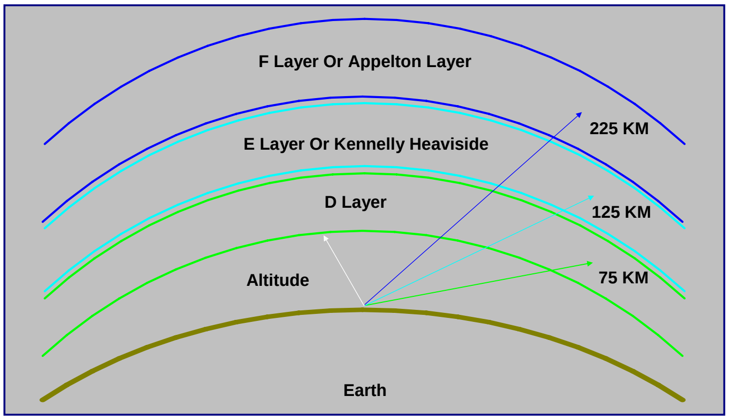


Ionosphere

The Ionosphere is a layer in the atmosphere that is electrically conductive. This layer is influenced by the presence of Ultra Violet radiation from the sun. The more radiation from the sun the more electrically conductive the layer becomes. As Ultra Violet radiation strikes the Ionosphere electrons are released from the gas, these electrons will affect an electromagnetic wave entering the Ionosphere. The radio wave will be refracted when entering the layer; the amount of refraction depends on the frequency of the radio wave. The higher the frequency the less the refraction. The Ionosphere can be divided into three layers:

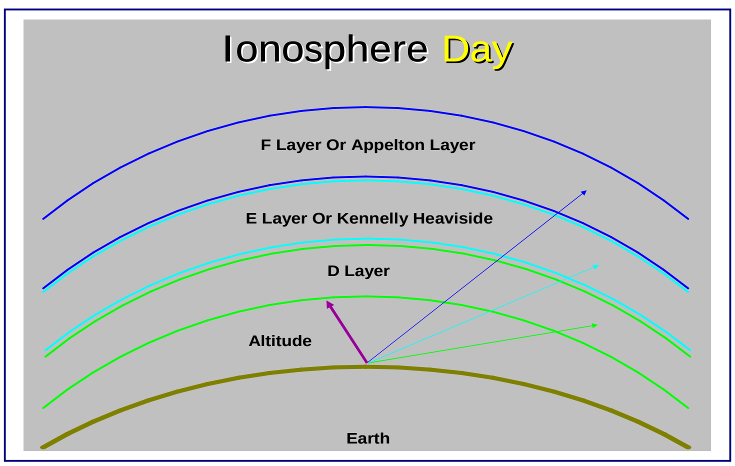
- D Layer
- E Layer or Kennelly Heaviside layer
- F Layer or the Appleton Layer: the F layer is divided into the F1 and F2 during the day

Ionosphere



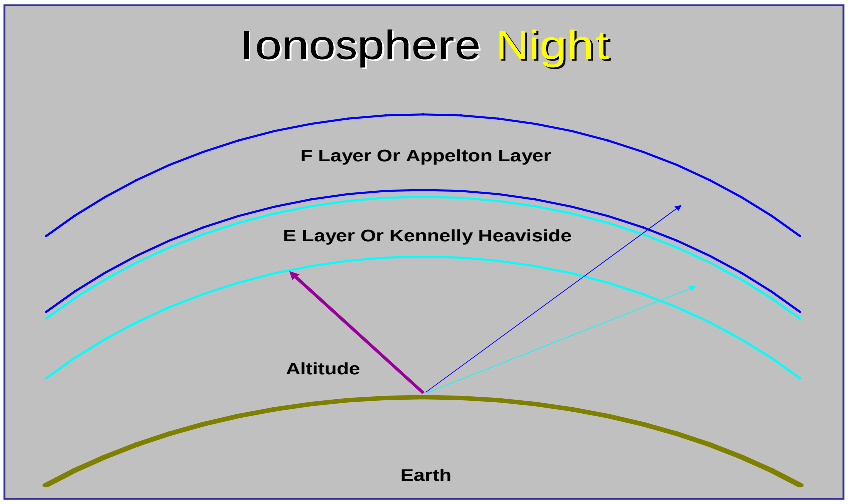
Properties of the Ionosphere

During the day there is a large amount of Ultra Violet radiation and therefore an abundance of free electrons in the Ionosphere. The Ionosphere is said to be very dense. All three layers are also present during the day and therefore the altitude of the Ionosphere is said to be low.



Properties of the Ionosphere

During the night the Ultra Violet radiation is significantly less and therefore the electrons return to their molecules and the Ionosphere density decreases. As there is a decrease in Ultra Violet radiation the D layer disappears and the height of the Ionosphere increases.



Refraction of Radio Waves

The Ionosphere is a layer that has electrical properties and thus affects an electro magnetic wave such as a radio wave. When a radio wave enters the Ionosphere the radio wave is slowed down and thus is bent or refracted by the Ionosphere. If the refraction is sufficient the radio wave will return to the earth as a sky wave. The amount of refraction depends on many factors such as the frequency of the radio wave, the density of the Ionosphere and the critical angle of the radio wave.

Frequency

As seen the higher the frequency the less the amount of refraction. A VHF radio wave will resist refraction and will not return to earth where as a HF radio wave will refract enough to return to earth.

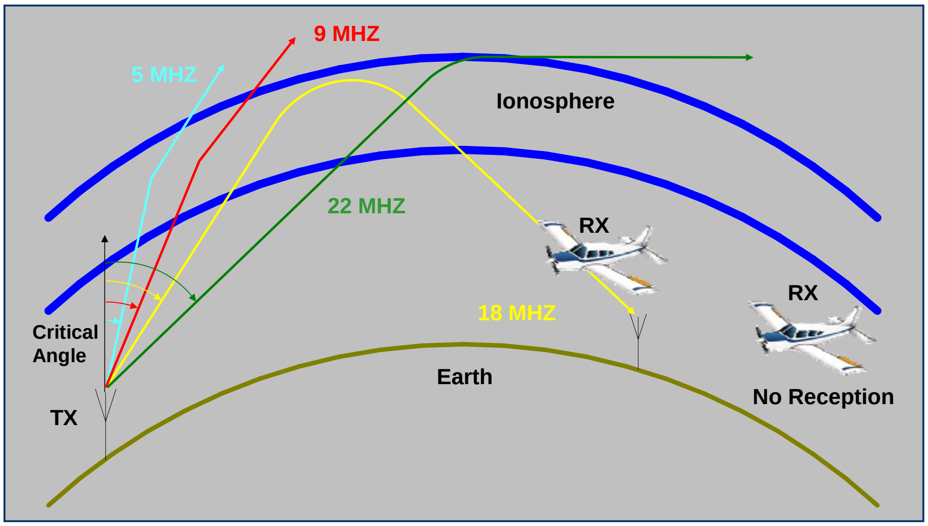
Density of the Ionosphere

During the day the Ionosphere is very dense and will refract higher frequencies back to earth than at night when the density of the Ionosphere is less dense.

Critical Angle

Critical Angle is the angle between the vertical and the direction of the radio wave travel.

As the frequency increases so does the Critical Angle, this is done automatically by antenna design. If a radio wave strikes the Ionosphere at right angles it will not return because it is not refracted. However, as the angle between the Ionosphere and the radio wave shallows the radio wave will start to refract. If the angle continues to shallow it will reach a point where the radio wave will refract enough to return to the earth. This frequency is called the minimum usable frequency. If the angle shallows too much the radio wave will reach a point where it will not return to earth. This is called the maximum usable frequency.



Seasonal Variations

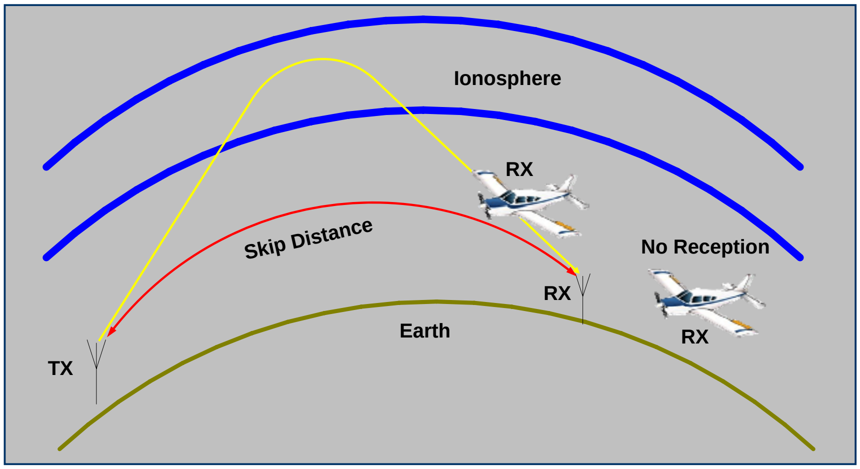
Ionospheric density depends on the sun. The closer the sun, the higher the density. The highest density can thus be expected in mid summer and the lowest density in mid winter.

Diurnal Variations

As seen the time of day will affect the height as well as the density of the Ionosphere. During sunrise and sunset the ionosphere layers are changing height and density. This will affect the way radio transmissions are transmitted and received i.e. NDB radios are unreliable at dusk or dawn.

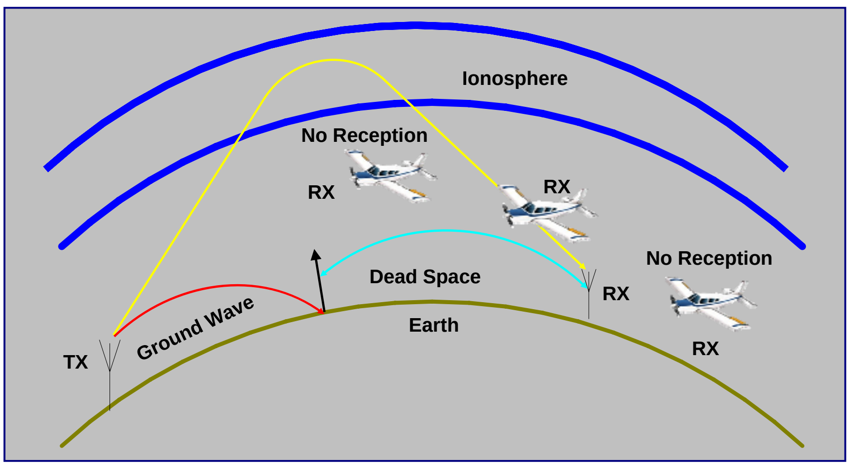
Skip Distance

Skip Distance may be defined as the distance from the transmitter to the first touchdown point on the earth. Note: not successive touchdown points.



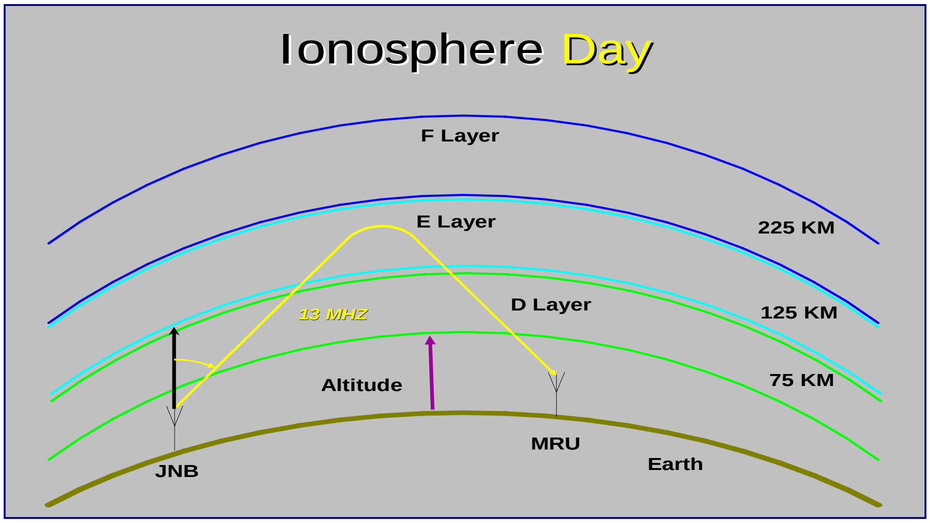
Dead Space

Dead Space may be defined as the distance between the termination of the ground wave and the first touchdown point of the sky wave.

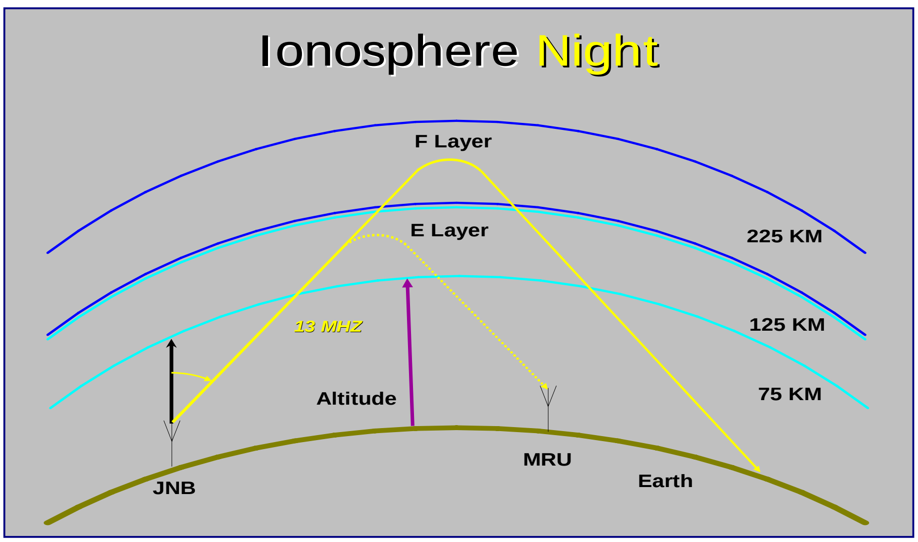


Practical Application of Sky Wave Propagation

Let's start by setting up the following conditions; we are talking to Mauritius on a frequency of 13 MHz during the day. As can be seen the D layer is present, therefore, the ionic density is high and capable of refracting higher frequencies. The altitude of the Ionosphere is low.

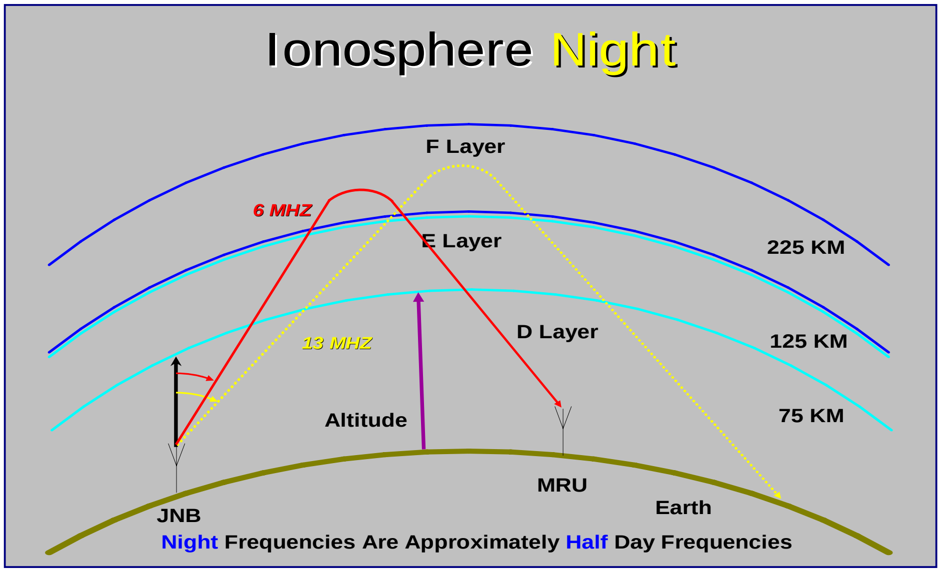


Let's now consider what will happen to the Ionosphere when the sun sets. As the sun sets the D layer will disappear and the altitude of the Ionosphere will increase while the density will decrease. If we continue to use the same frequency i.e. 13 MHz this frequency will have to penetrate further into the Ionosphere before it will be refracted. This will increase the Skip Distance placing the receiver in dead space.



Practical Application of Sky Wave Propagation

To correct this problem and get the receiver back into communication range we must reduce the Skip Distance. To do this the frequency of the radio wave must be reduced by approximately half of the day frequency. By reducing the frequency the radio wave will refract easier and the critical angle will reduce, thus reducing the Skip Distance.



Fading

Interference Fading

Interference Fading occurs when a single transmission arrives at a receiver as both a ground wave and a sky wave. If the signals are in phase the strength of the radio signal will be increased. If the signals are out of phase the signal strength will decrease. This variation in signal strength will cause the volume to increase and decrease.

Polarisation Fading

During refraction the radio wave will twist, changing the radio wave's polarisation. If the radio wave arrives at a horizontally polarised antenna as a vertically polarised wave the signal strength will be reduced. The converse is also true.

CHAPTER 2

VHF Communications

Very High Frequency (VHF) is used in short-range communication generally for air traffic control. VHF is static free but has some background noise.

Summary for VHF Communications

- The frequency band is from 118 MHz to 136 MHz; there are 720 channels and are spaced 25 KHz apart.
- VHF communications are vertically polarised.
- VHF communications are Amplitude Modulated and the type of emission is A3E.
- VHF radio waves are line of sight i.e. transmitted in straight lines, there is no refraction.
- The range of a VHF radio depends on the power of the radio but is approximately two hundred nautical miles.

CHAPTER 3

HF Communication

High Frequency (HF) is used for long-range communication. HF is relatively noisy with a lot of static.

Summary for High Frequency (HF) Communications

- The frequency band is from 2 MHz to 22 MHz.
- HF communications are Amplitude Modulated and can either be double sideband modulation or single sideband modulation.
- HF communications have A3E for double sideband or a J3E for single sideband emission.
- HF communications use the principal of sky wave propagation for transmission and have a range of approximately 4000 nautical miles if Ionospheric conditions are right.
- There is also a ground wave that is transmitted and has a range of 100 nautical miles.

CHAPTER 4

Selective Calling (SELCAL)

Selective Calling is used to relieve the pilots from listening to HF communications on long flights. SELCAL is available on VHF and HF communications and uses a set of coded tone pulses transmitted on the HF or VHF frequency currently selected. If a ground station has to establish communications with the aircraft it transmits two sets of coded tone pulses on the specific code of the aircraft. If the codes are correct the selcal decoder will illuminate a light with a warning tone on the flight deck.

Emergency Codes

• Aeronautical Emergency	121.5 MHz and 243 MHz
• International Distress	500 KHz and 2182 KHz
• Survival Craft	8365 KHz
• SSR Transponder	7700 Mode A or B

WORKSHEET 1

Basic Radio Theory

1. Weather Radar has a 3.2 cm wavelength. The transmission frequency is:

   a. 93.75 MHz
   b. 937.5 MHz
   c. 9.372 GHz

2. If a radio wave is horizontally polarised the:

   a. Electrical component is in the vertical plane and the magnetic component is horizontal.
   b. Electrical component is in the horizontal plane and the magnetic component is vertical.
   c. Magnetic component is horizontal with the electrical component 180° out of phase.

3. A disadvantage of a VLF is:

   a. High surface attenuation.
   b. Frequency instability.
   c. High static interference.

4. The propagation of sky waves is largely influenced by:

   a. The time of the day.
   b. Atmospheric attenuation.
   c. The earth's rotation.

5. With HF sky waves the skip distance:

   a. Increases with an increase in frequency.
   b. Increases with a decrease in frequency.
   c. Is constant for any frequency.

6. A radio wave usually increases in speed when crossing a coastline leaving the land and passing over the sea, resulting in:

   a. A change in frequency.
   b. A change in wavelength.
   c. No change in frequency or wavelength.

7. The degree of refraction of HF transmission by the ionosphere:

   a. Decreases as the frequency increases.
   b. Increases as the frequency increases.
   c. Is greater by night than by day.

8. Surface attenuation of a ground wave:

   a. Decreases as the frequency increases.
   b. Increases as the frequency increases.
   c. Increases as frequency decreases.

9. Ground waves in the VLF and LF frequency bands follow the curvature of the earth. This is due mainly to:

   a. Diffraction and surface attenuation.
   b. Refraction and surface attenuation.
   c. Diffraction and refraction.

10. Ground wave attenuation is greatest in the:

   a. LF frequency band.
   b. MF frequency band.
   c. HF frequency band.

11. With Amplitude Modulated transmissions:

   a. The frequency is constant and the amplitude varies.
   b. Both the frequency and amplitude vary.
   c. The amplitude is constant and the frequency varies.

12. With Frequency Modulated transmissions:

   a. The frequency is constant and the amplitude varies.
   b. Both the frequency and amplitude vary.
   c. The amplitude is constant and the frequency varies.

13. Static interference is most severe in the:

   a. VHF frequency band.
   b. MF frequency band.
   c. VLF frequency band.

14. Changing a HF/RT frequency from 13315 KHz to 6559 KHz would result in:

   a. An increase of the dead space.
   b. An increase of the critical angle.
   c. A decrease of the skip distance.

15. A carrier wave with amplitude of 5 V is amplitude modulated by an audio frequency with V amplitude. The resultant depth of modulation is:

   a. 48%.
   b. 80%.
   c. 125%.

16. The HF/RT frequency that would most likely result in communication with Johannesburg at 2200Z is:

    a. 6559 KHz.
    b. 17955 KHz.
    c. 21926 KHz.

17. If frequency of 4 Hz was transmitted for one second the physical space occupied by the signal would be:

    a. 75 000 000 metres.
    b. 150 000 000 metres.
    c. 300 000 000 metres.

18. A SELCAL transmitted code consists of two RF pulses. The aircraft receiver is activated by:

    a. The spacing between the two pulses.
    b. The modulated tone of the pulses.
    c. The length of the pulses.

19. VHF R/T receivers usually incorporate a squelch control which:

    a. Narrows the beamwidth and extends the range.
    b. Prevents feedback if hand held microphones are used.
    c. Disables the receiver output when no signals are being received so preventing noise being fed to the crew headsets.

20. Sidebands are additional frequencies which occur when a carrier wave is:

    a. Modulated by a frequency lower than itself.
    b. Frequency modulated.
    c. Pulse modulated.

21. Advantages of single side band transmissions are:

    a. Broader bandwidth and a power saving as one or two frequencies are transmitted instead of three.
    b. Narrower bandwidth and greater range as the power output is concentrated in one or two frequencies instead of three.
    c. Broader bandwidth and better signal quality as three frequencies are used.

22. During the night the HF R/T frequencies used are approximately half the day time frequencies because:

    a. At night the height of the reflecting layer increases and a lower frequency produces a smaller critical angle thus reducing dead space.
    b. A lower frequency increases the range of the ground wave thus balancing the increased distance of the first sky wave return.
    c. The density of the ionosphere reduces and the higher frequencies are not reflected.

23. Skip distance is the distance between:

    a. Successive skywave touch down points,
    b. The distance between the end of the ground wave and the first skywave return.
    c. The distance between a transmitter and the first skywave return.

24. A radio wave modulated at a single audible frequency (keyed CW) is classified:

    a. A1A.
    b. A2A.
    c. A3A.

25. Reception of HF communications by night is affected by:

    a. The lower ionosphere density.
    b. The height of the reflective layer is reduced.
    c. HF communications are not affected.

26. The HF frequencies used at night for communication are:

    a. Twice the day frequency.
    b. Half the day frequency.
    c. The same as the day frequency.

27. The wavelength of a radio wave is:

    a. The number of complete cycles transmitted in one second.
    b. The distance travelled by a radio wave in one second.
    c. The distance travelled by a radio wave in one cycle.

28. The ionospheric density of the E layer of the ionosphere is a it greatest at:

    a. Midday in summer.
    b. Midday in winter.
    c. Midnight in summer.

29. The maximum theoretical VHF communication range between an aircraft flying at FL 200 and a control tower 255 ft AMSL is:

    a. 197 sm.
    b. 226 nm.
    c. 364 km.

30. A horizontally polarised radio wave has its:

    a. Electrical filed in the horizontal plane.
    b. Electrical field in the vertical plane.
    c. Magnetic field in the horizontal plane.

31. The F layer of the ionosphere:

    a. May split into two layers.
    b. Is weaker than the other layers.
    c. Is the lowest layer of the ionosphere.

32. The critical angle of a radio wave:

    a. Varies with frequency.
    b. Varies with phase angle.
    c. Is constant for all frequencies.

33. International distress frequencies are:

a.	500 KHz	121.5 MHz	243 MHz	8364 MHz.
b.	243 KHz	121.5 MHz	500 KHz	8364 KHz.
c.	500 KHz	121.5 MHz	243 MHz	8364 KHz.

34. Ground wave attenuation is greatest on:

    a. VLF.
    b. MF.
    c. HF.

35. Bending of a radio wave by the earth's surface is greatest on:

    a. VLF.
    b. MF.
    c. HF.

36. The F layer of the ionosphere is also called the:

    a. Kenelly - Heaviside layer.
    b. Appleton layer.
    c. Gauss layer.

37. The VHF voice communication frequencies are:

   a. 108 to 112 MHz.
   b. 108 to 117.9 MHz.
   c. 118 to 136 MHz.

CHAPTER 5

Automatic Direction Finding (ADF)

Automatic Direction Finding (ADF) is still used for aircraft navigation. ADF is designed to receive low to medium frequencies to indicate to the pilot where the station or NDB is. This is done by measuring the direction of the incoming signal, using the fore-aft axis of the aircraft as the reference. This measurement is called the Relative Bearing. The information is displayed on one of two indicators i.e. the Relative Bearing Indicator (RBI) or the Radio Magnetic Indicator (RMI).

Summary for ADF

Frequency

The frequency range of the ADF is in the low to medium frequency band, but the radio is considered to be a medium frequency radio aid. The frequencies are allocated by ICAO and are 190 KHz to 1750 KHz. However, the normal range in which NDB stations are found is between 200 KHz to 500 KHz.

Transmission of the NDB Station

The transmission of the ground station is an Omni-Directional Vertically Polarised signal. In this frequency range both sky and ground waves are transmitted but only the ground wave is used for navigation.

Range of the NDB Station

The range of a NDB station is approximately 300 nautical miles over land and approximately 1000 nautical miles over water.

Emission of NDB Station

A1A – Carrier wave only with identification by switching the carrier wave on and off.
A2A – Carrier wave with identification by single tone modulation.

Navigation

Used as secondary navigation, to supplement ILS marker beacons. Used for approach and holding and reporting positions on airways.

Identification

NDB stations, except locator NDB stations, transmit a three letter Morse Code. Locator NDB's transmit a two letter Morse Code.

Aircraft Equipment

ADF Receiver

This is the radio in the aircraft used to select NDB frequencies and to determine the direction of the NDB station. The ADF receiver uses the information from two aerials namely, the Loop Aerial and the Sense Aerial.

ADF Function Switches

Frequency Selectors

This is used to select the required frequency of the required NDB station. The range is from 190 KHz to 1750 KHz.

ANT / REC Switch

In this position the Sense Antenna is used to tune and identify the NDB station. The Loop Antenna is disconnected.

ADF Switch

In this position both the Loop and Sense Antennas are connected. This id's the normal position for the switch to receive bearing information, required for navigation.

BFO Switch

In this position the Beat Frequency Oscillator (BFO) is switched on to identify an A1A NDB station. The BFO should be switched off during the use of an A2A NDB station.

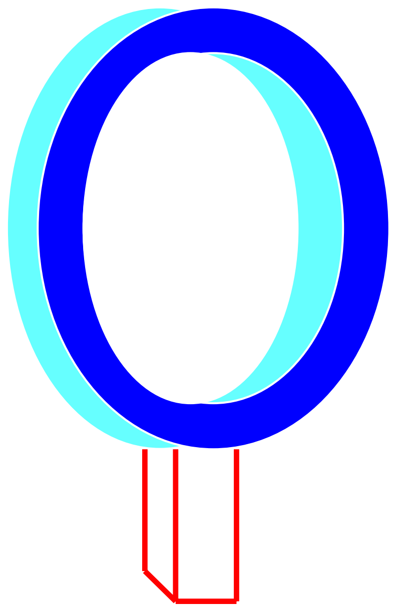
Test Switch

This switch is used to test the operation of the ADF receiver. Note that there are no flags to indicate that the system is not working. Only the relative bearing pointer indicates that the system is working by pointing in a particular direction as indicated in the system handbook.

Aircraft Equipment

Loop Aerial

The Loop Aerial discussed in this chapter is of the older type and is called the rotating loop. The newer aerial is fixed but uses the same principal of operation and is called a Bellini Tosi Aerial. This type of aerial is normally mounted on the bottom of the fuselage. The Loop Aerial is mounted in the vertical plane and is able to rotate. It may be considered to look like a circle as in the first diagram. The vertical sides of the circle are designed to receive radio signals from the NDB station. In the construction of the aerial a wire strand is wound around a frame to achieve the required length of the aerial for the low to medium frequency band. As will be seen later in this chapter, this type of aerial is directional and will produce a 180º ambiguity or uncertainty.



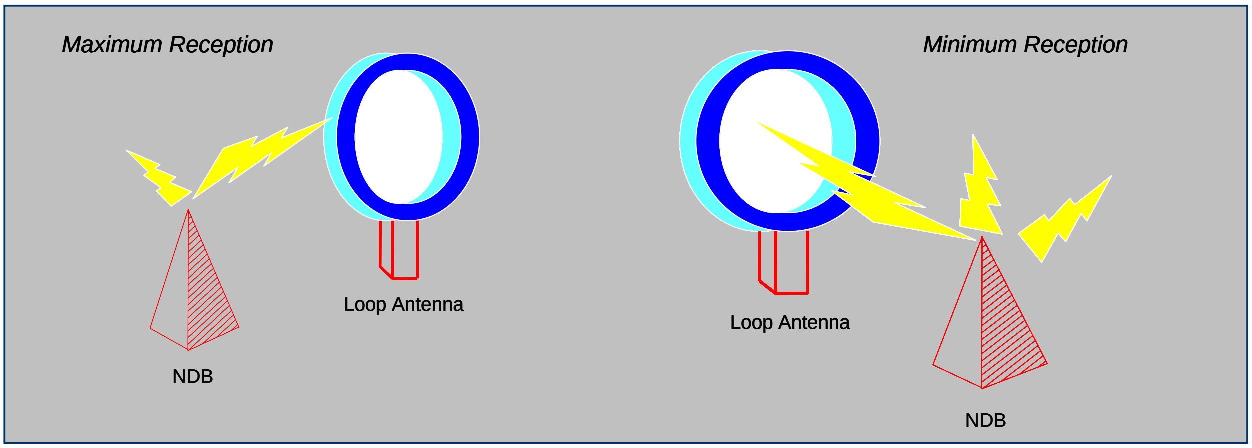
Rotating Loop aerial

Fixed Loop aerial

Principal of Operation of the Loop Aerial

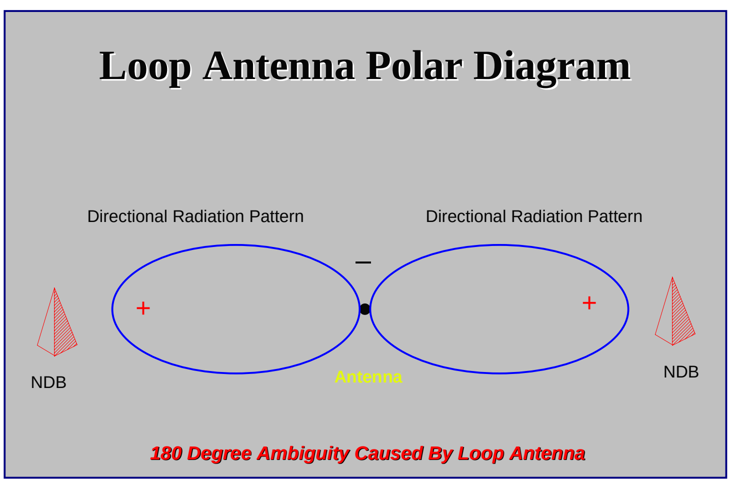
When the aerial lies in the same plain as the incoming signal, the radio energy is induced in the vertical sides of the aerial producing a current flow in both sides of the aerial. Due to the one side being farther than the other from the station a phase difference is produced.

When the aerial is at right angles to the radio station no radio energy is induced into the aerial. Because the vertical sides of the aerial are the same distance from the radio station and no phase shift occurs there will be no current flow. This is said to be the null position of the aerial. If the aerial lies between the maximum position and the null position the amount of induction into the aerial is proportional to the cosine of the angle between the Loop Aerial and the NDB station.



Polar Diagram of the Loop Aerial

The final polar diagram produced by the Loop Aerial is directional i.e. the aerial only receives when the vertical sides face the radio station or NDB and is in the form of a figure of eight. This diagram presents a problem for navigation as the station can now be in one of two places, either in front of the aerial or the back of the aerial. The Loop Aerial produces an 180º ambiguity. This ambiguity will be resolved by the other aerial used by the ADF called the Sense Aerial.

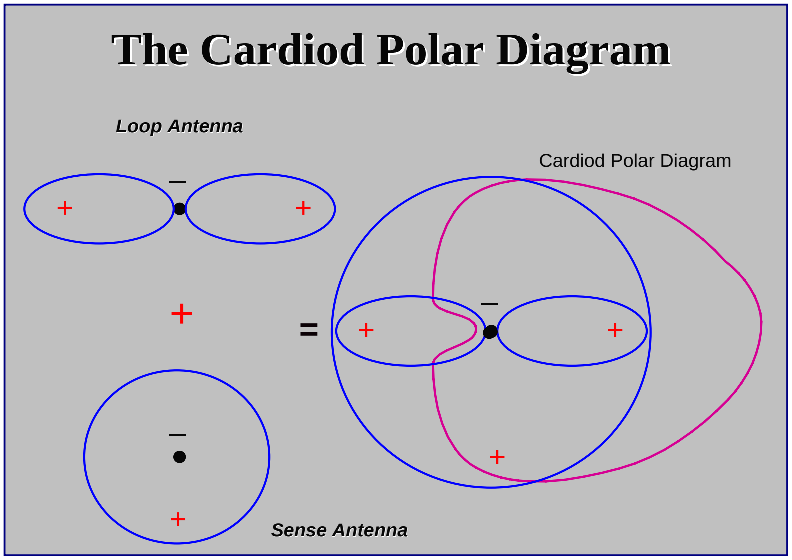


Sense Aerial

The Sense Aerial is used to resolve the 180º ambiguity produced by the Loop Aerial. This aerial is omni-directional and produces a circular polar diagram. This aerial is also used to receive the identification of the NDB station.

The Cardioid Polar Diagram

The combination of the Loop and Sense Aerials are used to produce a third polar diagram, called the Cardioid Polar Diagram. This polar diagram has a large positive area and a very small specific null point. By using the null point the direction of the NDB can be found and the 180º ambiguity can be resolved. The indications can then be displayed on either a RBI or a RMI indicator in the aircraft.



Direction

Before we can look at how the Relative Bearing Indicator and the Radio Magnetic Indicator are used in the aircraft for navigation we must first understand the rules and application of the following terms:

- True heading
- Magnetic heading
- Variation
- Compass heading
- Deviation
- Heading
- Track
- Relative bearing
- QDM
- QDR
- QUJ
- QTE

- **True Heading** : Working On A **Map**
- **Magnetic Heading** : Working With A **Land Compass**

Use *Variation* To Convert From One To Another

Variation W +
Variation E -

True Heading ± Variation = Magnetic Heading

TH ± VAR = MH

- **Compass Heading** : Working With An **Aircraft Compass**
- **Magnetic Heading** : Working With A **Land Compass**

Use *Deviation* To Convert From One To Another

Deviation W -
Deviation E +

Compass Heading ± Deviation = Magnetic Heading

CH ± DEV = MH

- **Heading** : The Direction True Or Magnetic Where The **Nose** Of The Aircraft Is
- **Track** : The Line The Aircraft Draws On The **Ground**

Use *Drift* To Convert From One To Another

Aircraft Drifting Left Turn Nose Right
Aircraft Drifting Right Turn Nose Left

Q Codes

- **QDM** : **Magnetic** From Aircraft To Station
- **QDR** : **Magnetic** From Station To Aircraft
- **QUJ** : **True** From Aircraft To Station
- **QTE** : **True** From Aircraft To Station

- **Relative Bearing** : The Angle Measured From The **Fore Aft Axis** Of The Aircraft In **Clockwise** Direction
- **Heading** : The Direction True Or Magnetic Where The **Nose** Of The Aircraft Is

Relative Bearing Can Not Be Used By Itself

	True Heading		**Magnetic Heading**
+	**Relative Bearing**	+	**Relative Bearing**
=	**QUJ**	=	**QDM**

Aircraft Equipment

Relative Bearing Indicator:

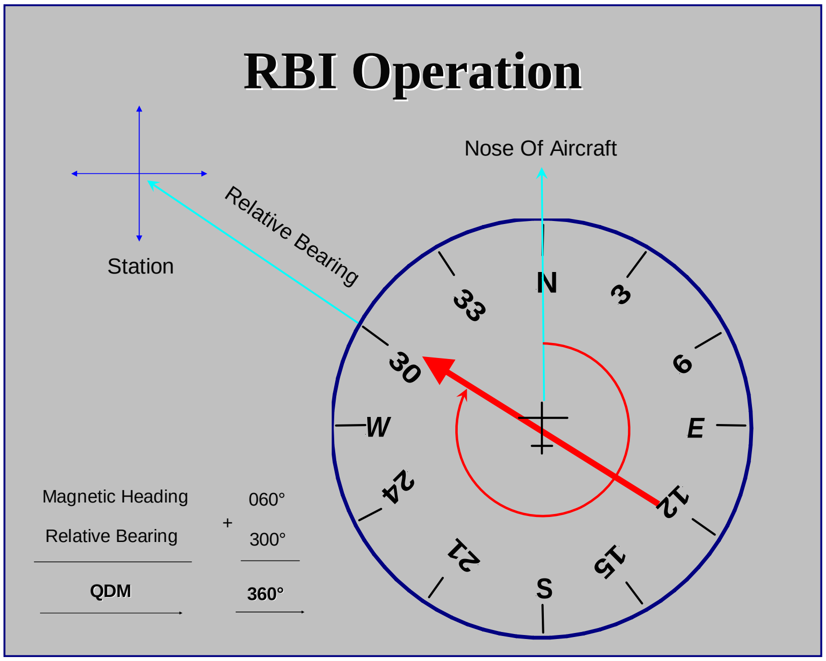
The Relative Bearing Indicator has a direction card with 360º fixed to the fore-aft axis of the aircraft. The numbers on the card show the angles from the nose of the aircraft in a clockwise direction, known as relative bearings. The numbers on the card do not indicate magnetic or compass direction. The ADF pointer on the card simply indicates the angle from the nose of the aircraft to the selected NDB station i.e. points to the station.

Relative Bearing Operation

Relative bearings cannot be used by themselves because they only show the angle between the nose of the aircraft and the selected station. The aircraft compass heading must be used to obtain the QDM, which is the magnetic track from the aircraft to the station. However, the compass heading must be converted to a magnetic heading before it is used in the calculation, so deviation must be used to convert from compass heading to magnetic heading.

If we were to plot this information on a map we would have to use variation at the aircraft to convert the magnetic information to true information known as a QUJ. The variation at the aircraft is used because the information obtained from the aircraft compass is reading the variation at the aircraft.

We must also note that one cannot plot from the aircraft to the station QUJ, as the position of the aircraft is unknown. We now have to plot a true line from the station to the aircraft known as a QTE. More on navigation plotting will be covered in the Navigation subjects.

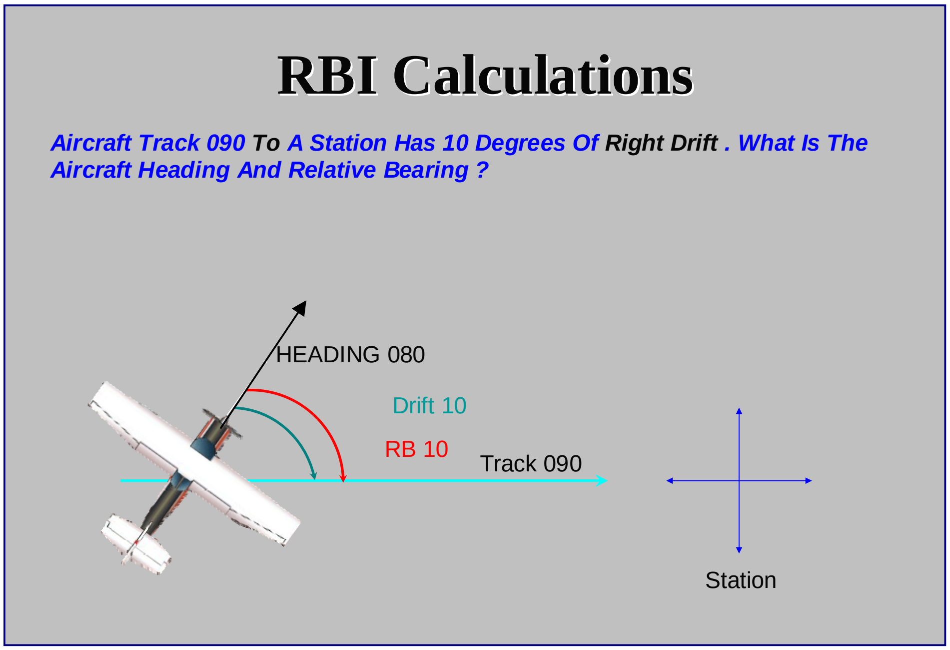


Relative Bearing Calculations

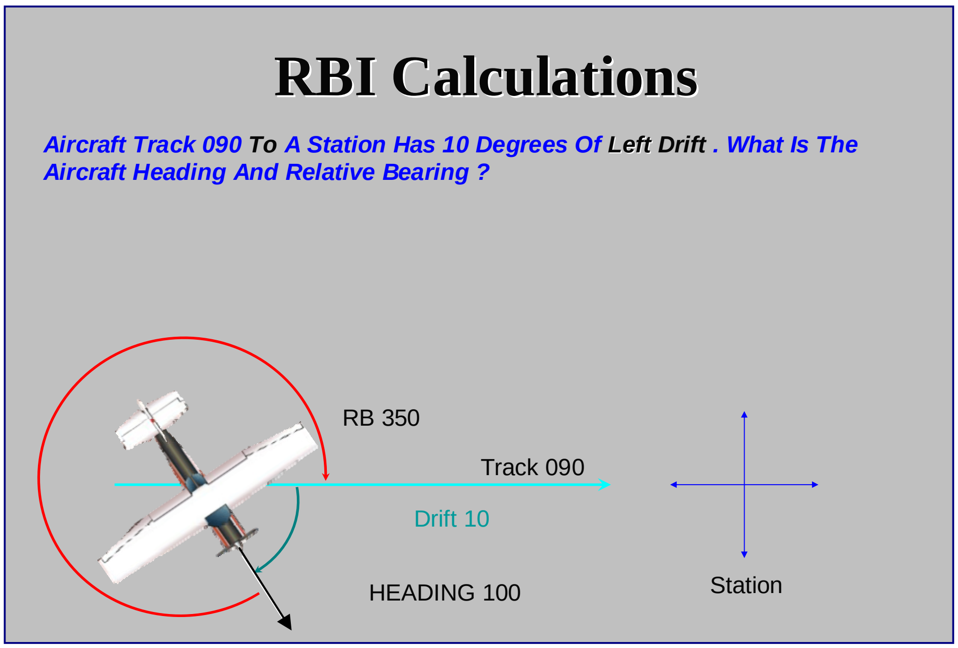
Relative bearing calculations will fall into one or more of four basic calculations. If the type of calculation can be identified it is simple to solve the problem. The four basic types of calculations are as follows:

- Aircraft tracking to a station with left drift.
- Aircraft tracking to a station with right drift.
- Aircraft tracking from a station with left drift.
- Aircraft tracking from a station with right drift.

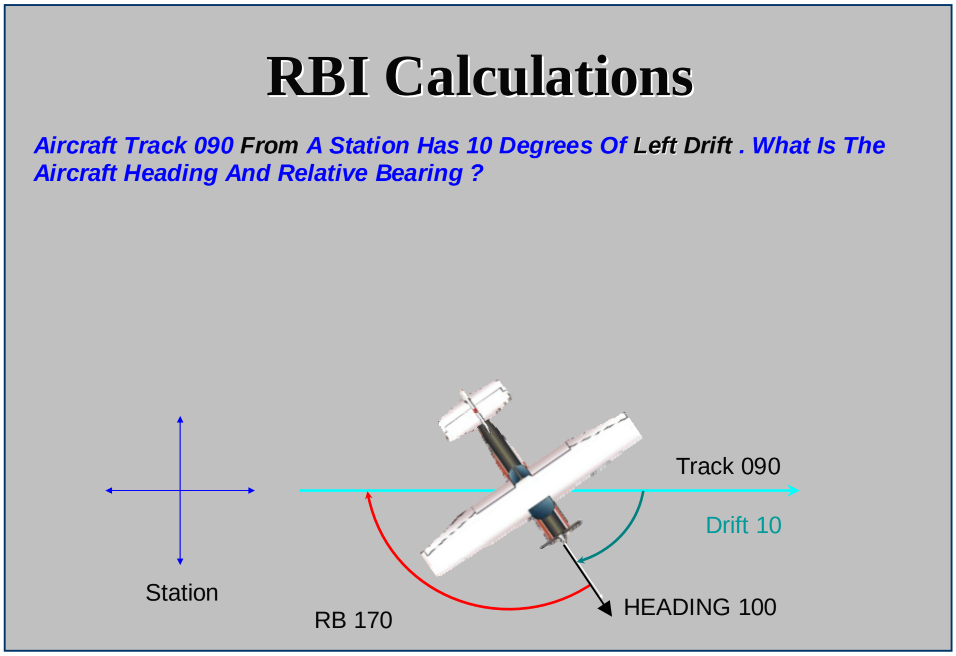
Example No 1



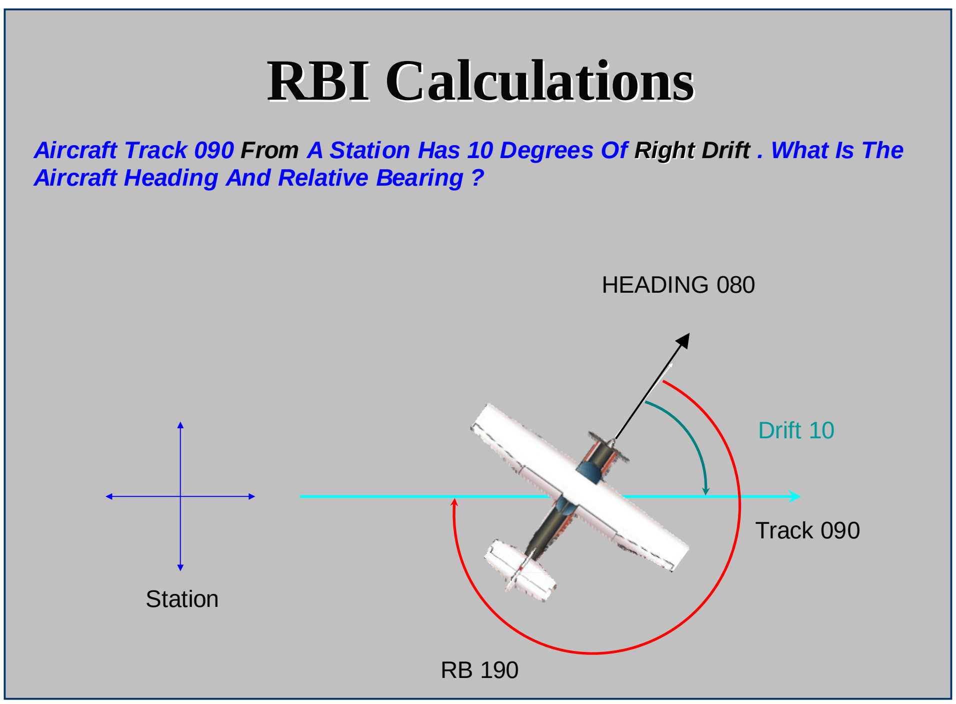
Example No 2



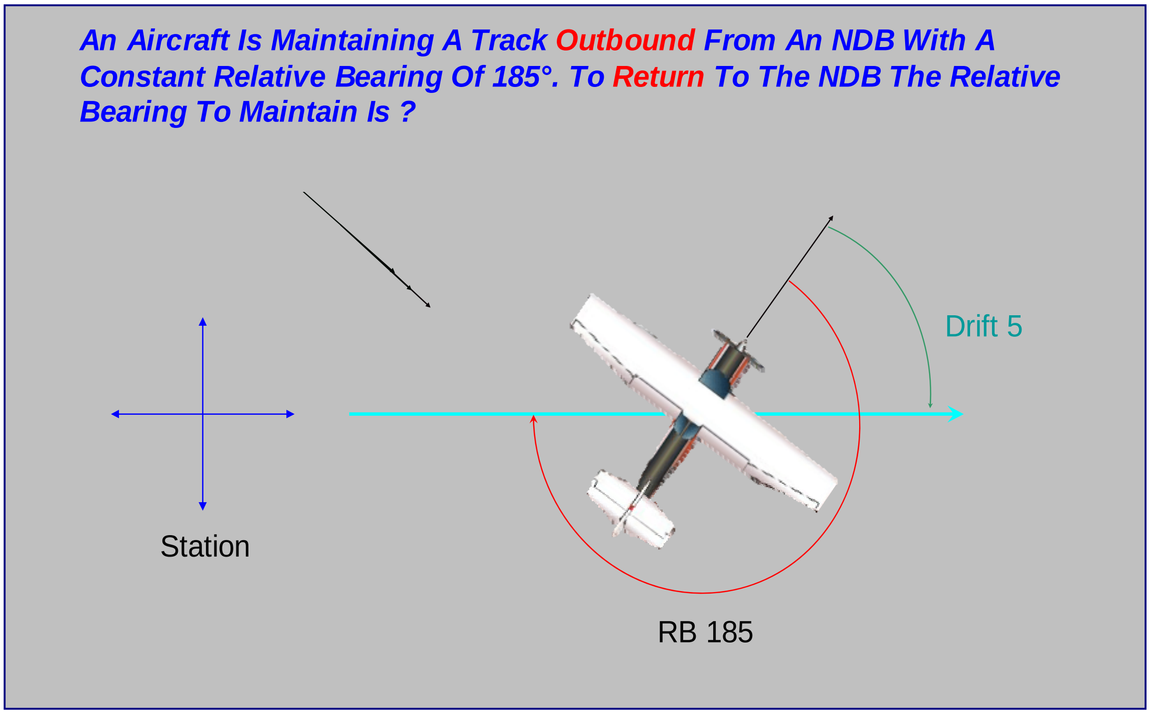
Example No 3



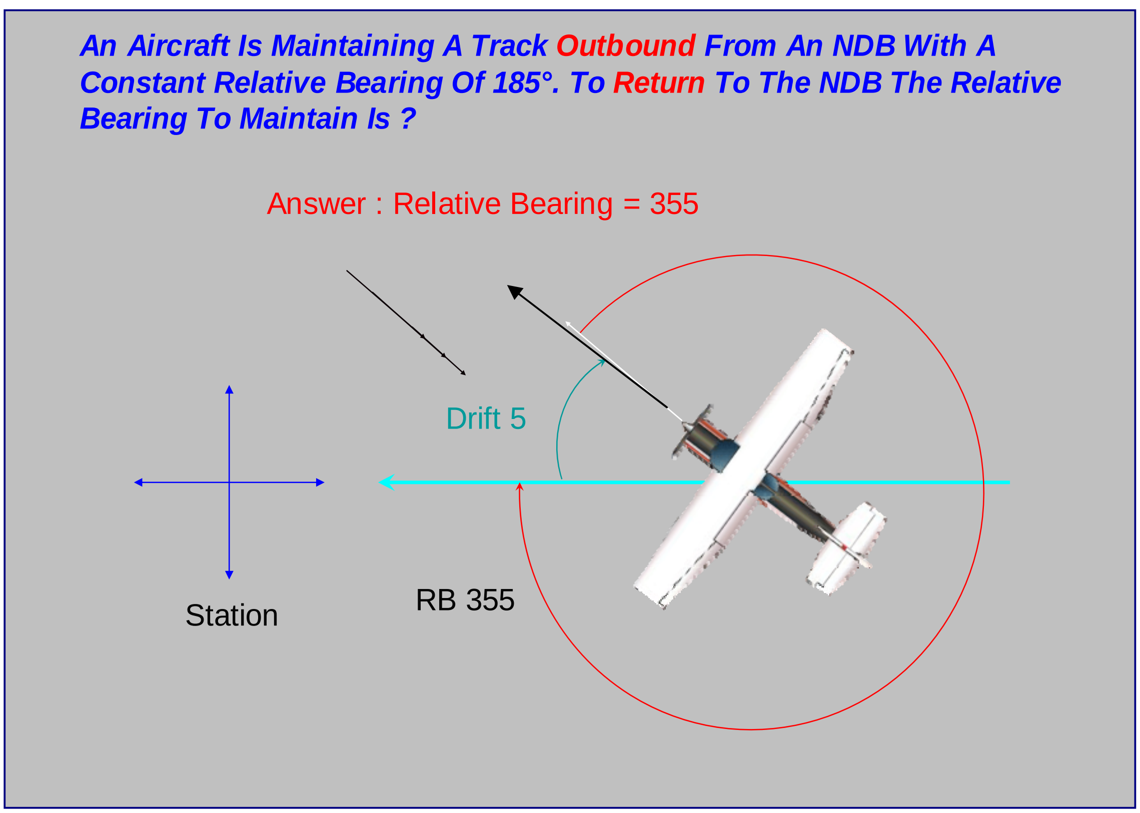
Example No 4



General Example No 1



General Example No 1 Continued



General Example No 2

An Aircraft Heading 157° True, Variation 15° W Has A Relative Bearing Of 193° From NDB CD What Is The QDM To NDB CD ?

1. True Heading ± Variation = Magnetic Heading

   157° + 15° = 172°

2. Relative Bearing 193°

   \+ Magnetic Heading + 172°

   = **QDM** **365°** **Or** **005°**

Aircraft Equipment

Radio Magnetic Indicator

The Radio Magnetic Indicator has a rotating compass card that is slaved to the aircraft gyrocompass system and shows aircraft compass heading. The ADF pointer still works in exactly the same way as on the RBI in that the needle points to the NDB station i.e. the angle between the nose of the aircraft and the station known as the relative bearing. The ADF pointer does not need the compass card to work, as the card is not used in the ADF system. They are two separate systems. If the compass card does not work the ADF pointer will work and the needle will point to the station. Dual pointer RMI indicators can display two different NDB stations at the same time, the double needle displays system two and the single needle displays system one.

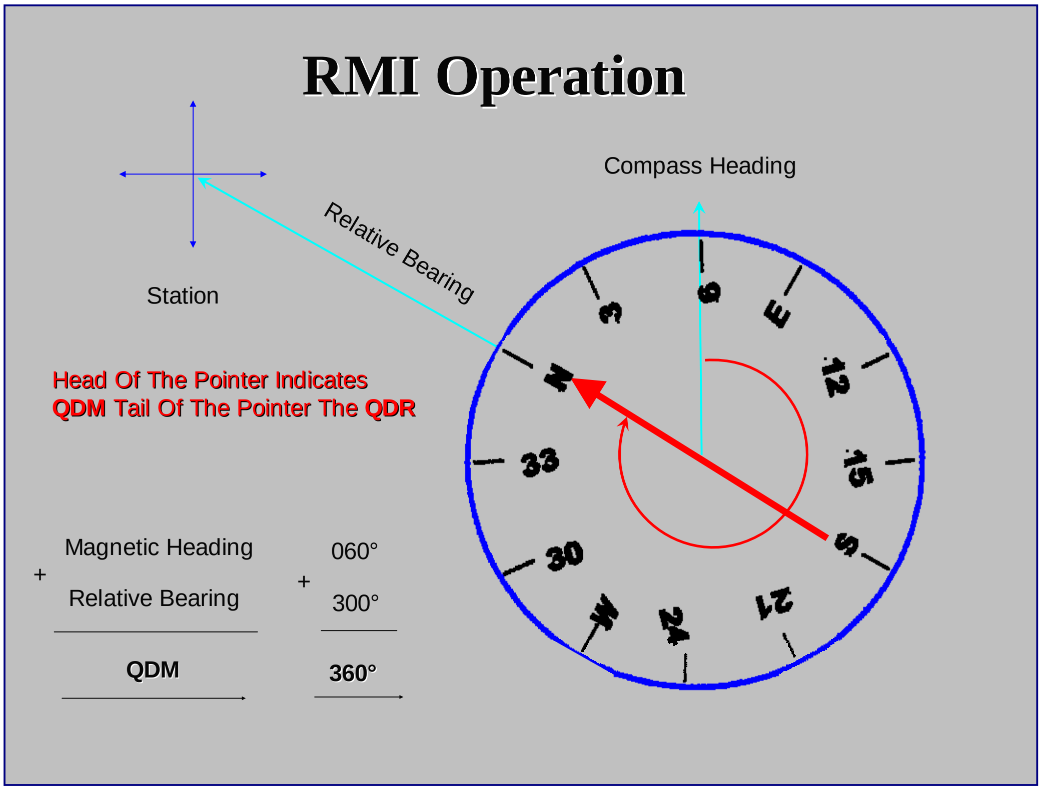
Radio Magnetic Indicator Operation

The advantage of using a RMI is that information can be obtained more easily than from a RBI. There is, however, a consideration when using a RMI to obtain bearings and that is the fact that the compass system measures compass heading. Therefore, QDM and QDR cannot be read directly from the RMI if there is deviation in the aircraft.

The compass heading must be converted to magnetic heading using deviation before the QDM or QDR can be determined. If the information is to be plotted on a map then the variation at the aircraft must be used as the information from the RMI is magnetic and the plot on a map is true. Use the variation at the aircraft as the compass system uses the variation at the aircraft. If there is no deviation then the QDM is indicated by the head of the needle and the QDR by the tail of the needle.

Radio Magnetic Indicator Operation

Because compass heading is shown the entire time, one does not have to do the calculation manually as in the RBI. QDM and QDR can be read off the indicator if there is no significant deviation on the compass system.



As can bee seen the compass heading is under the lubber line of the aircraft. The ADF pointer points to the station i.e. the relative bearing. The head of the pointer shows the QDM of 360º and the tail of the pointer shows the QDR of 180º. The calculation is done automatically In the RMI.

Factors Affecting the Accuracy of a NDB

Night Effect

As the NDB station transmits in the medium frequency band it produces both sky and ground waves. This results in the ADF receiving both waves at the same time. As the waves travel different distances they will be out of phase and in different directions resulting in incorrect bearing information being displayed on the indicators. As the ADF will receive both waves at the same time, the pointer will wander. This error is most pronounced during dusk or dawn because the Ionosphere is changing in altitude and density.

Thunderstorms

Thunderstorms emit high amounts of electromagnetic energy. The ADF points to this energy instead of the NDB station resulting in errors.

Mountain Effect

High ground will reflect medium frequency radio waves from the NDB station resulting in the ADF in the aircraft receiving signals from different directions at the same time. This causes an oscillation of the ADF pointer. Errors can exceed 10º and can be reduced by flying higher.

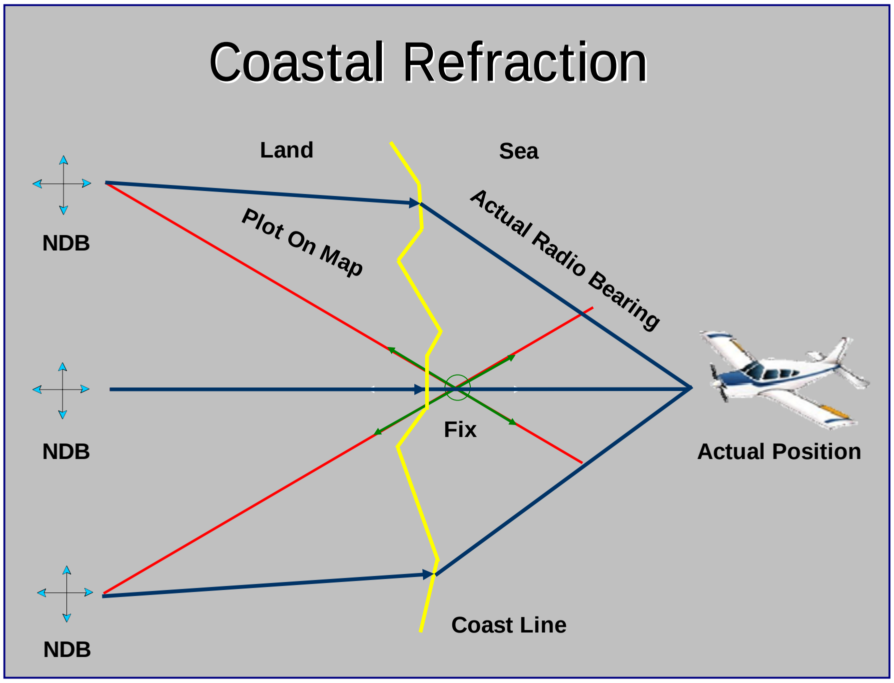
Quadrantal Error

These errors are caused by the re-radiation of radio waves from the metal parts of the aircraft. Signals received from the cardinal points are not affected but signals received from 45º from the cardinal points i.e. in the quadrants will have the greatest error.

Station Interference

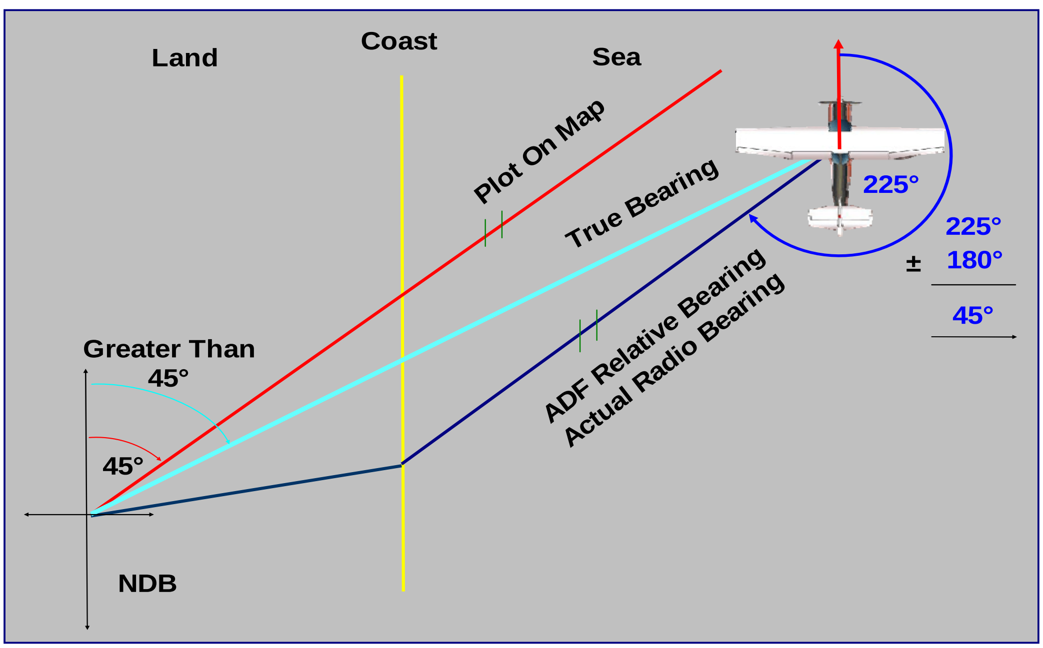
This is caused by different NDB stations on the same frequency being received by an aircraft at the same time. This causes the ADF pointer to oscillate between the two stations. The NDB stations are placed far enough apart to prevent this problem during the day, but the problem may occur at night and caution must be used when using ADF navigation at night.

This is caused when a radio wave travels from a more dense medium such as ground to a less dense medium such as water causing the radio wave to change speed or refract. The more oblique the angle at which the radio wave strikes the coast the greater the refraction. If the radio wave strikes the coast at 90º there will be no refraction.



Coastal Refraction Calculation

The coastline lies north south. An aircraft over the sea receives an ADF bearing of 225º relative. What is the true bearing with respect to the plot?



Factors Affecting the Range of a NDB

Surface Attenuation

The range is greater over water than land. Typically 300 nautical miles over land and approximately 1000 nautical miles over water.

NDB Transmitting Power

The higher the power output of the NDB station the greater the range. To double the range the power must be increased by four times.

NDB Transmitting Frequency

The lower the NDB frequency the less the ground wave attenuation and the further the range.

ADF Receiver Quality

The more sensitive the receiver the smaller the incoming signals can be to still be detected by the radio.

Precipitation Static

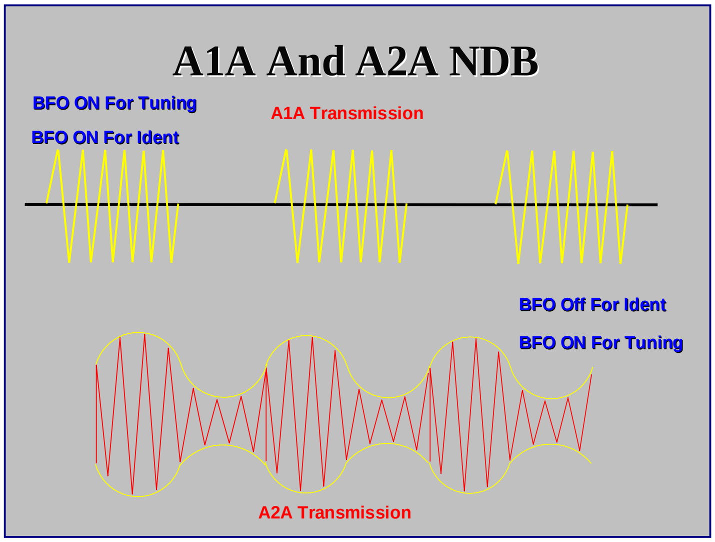
The presence of precipitation against the airframe causes the ambient noise to increase and reduces the receiver sensitivity.

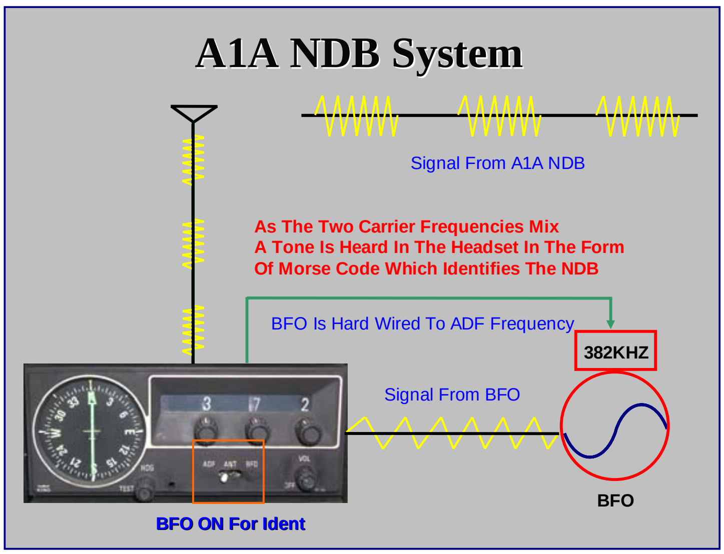
Type of Emission of a NDB Station A1A and A2A

There are two types of NDB transmitting stations, A1A which is an old type of beacon and an A2A station, which is a new type of beacon. Below are the properties of both types of Stations:

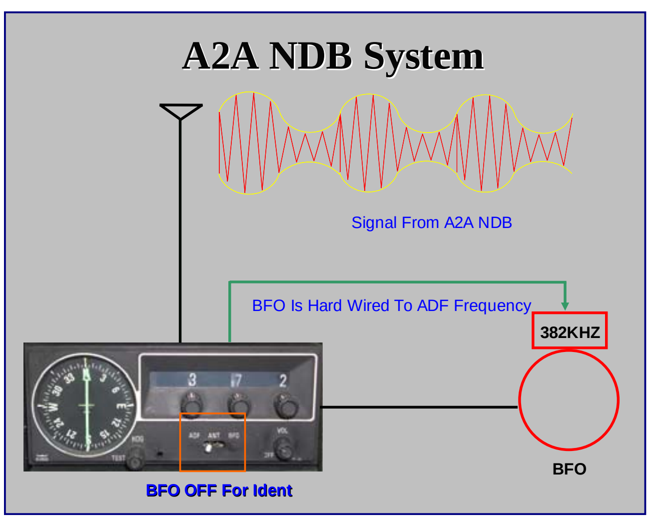
- An A1A station is older than A2A station.
- A1A has a longer range than an A2A.
- The ADF pointer wanders during the transmission of an A1A signal but not with an A2A.
- No modulation is used for identifying an A1A; it is a Keyed Continuous Wave.
- The A2A uses modulation for the identification; it is an Amplitude Modulated radio.
- An A1A is identified on a chart as an underlined station identifier.
- The A2A station identifier is not underlined.
- To identify an A1A NDB the BFO must be on.
- To identify an A2A the BFO must be off.
- To tune an A1A the BFO must be on.
- To tune an A2A the BFO must be on.

Type of Emission of a NDB Station A1A and A2A





Type of Emission of a NDB Station A1A and A2A



ADF Interception Calculations

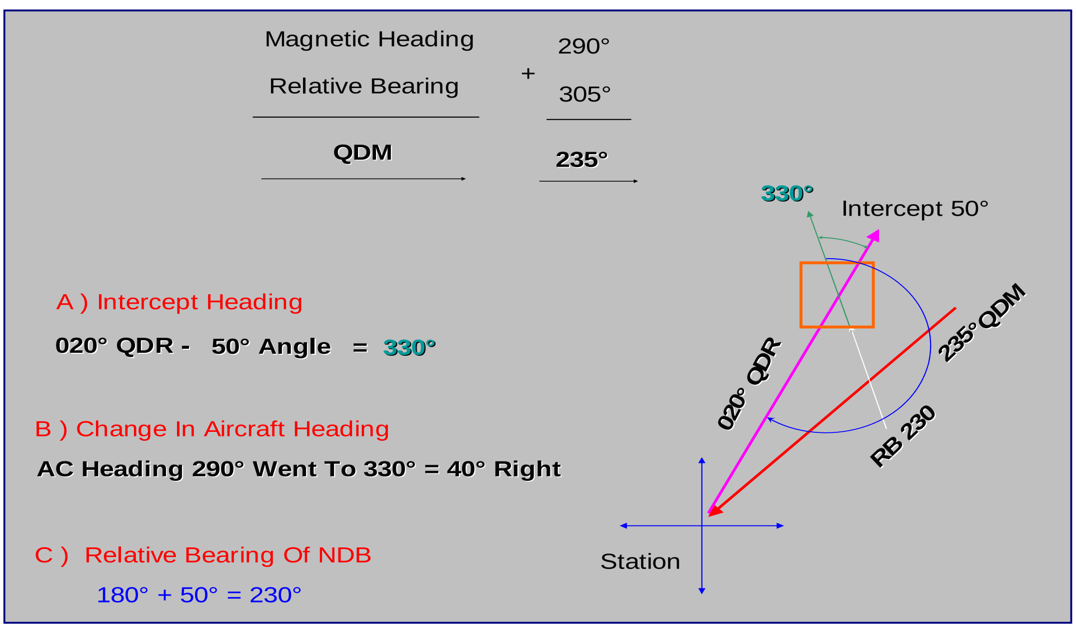
These questions are the theoretical applications of intercepting required tracks inbound to a NDB station or outbound from a NDB station i.e. QDM and QDR intercepts. Below is the step method for solving these types of questions.

Method

- Calculate and plot the QDM.
- Plot the track to be intercepted. Note if inbound or outbound.
- Plot the intercept angle on the intercept track not if the aircraft is inbound or outbound.
- .
- Close the triangle; this is a check that the drawing is correct.
- Calculate all the answers at the point of intercept.
- Calculate the following:
    - The aircraft intercept heading.
    - The change in aircraft heading.
    - The relative bearing of the NDB station.

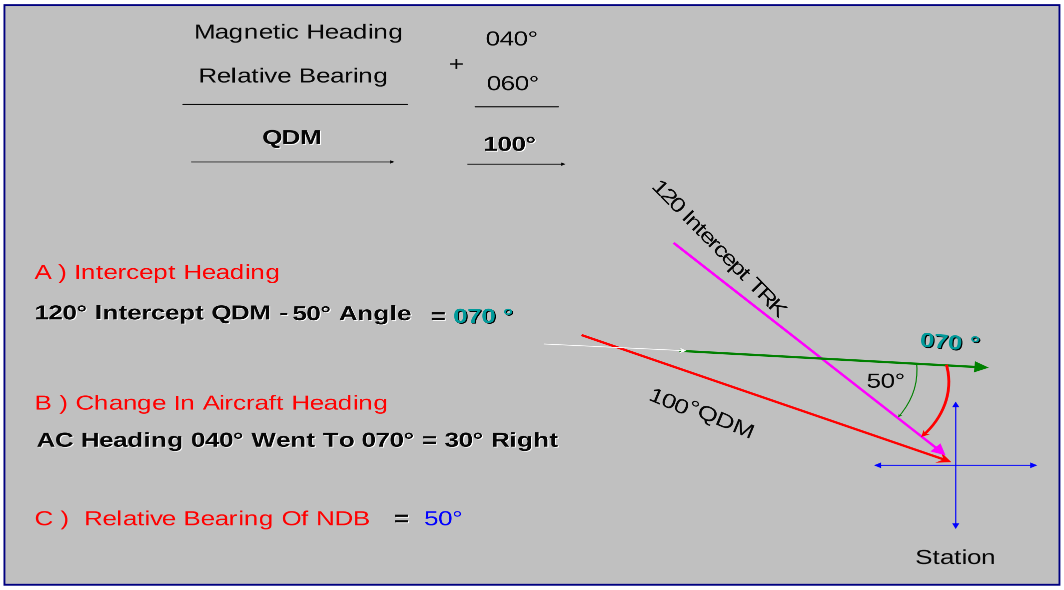
ADF Intercept Calculations Example No 1

An aircraft heading 290º magnetic has an ADF reading of 305º relative from a NDB station. ATC instructs the pilot to intercept the 020º QDR at an angle of 50º. Calculate the intercept heading, the change in aircraft heading and the relative bearing of the NDB station.



ADF Intercept Calculations Example No 2

An aircraft heading 040º magnetic has an ADF reading of 060º relative from a NDB. ATC instructs the pilot to intercept the 120º QDM at an angle of 050º. Calculate the intercept heading, the change in aircraft heading and the relative bearing of the NDB.



Time and Distance to a NDB

This is a quick method to calculate the time and distance to a NDB or any other station.

Time and Distance Calculation Example No 1

At 09H00 a relative bearing of 258º is obtained from a NDB. At 09H08 a relative bearing of 272º is obtained from the same NDB, the TAS is 140 Kts. If the aircraft alters heading at 09H08 to fly to directly to the NDB, what is the time and distance to the NDB?

$$\textbf{Time To The NDB} = \frac{60 \times \text{Minutes Flown Between Bearings}}{\text{Degrees Of Bearing Change}}$$

$$\textbf{Distance To The NDB} = \frac{\text{TAS/GS} \times \text{Minutes Flown Between Bearings}}{\text{Degrees Of Bearing Change}}$$

$$\textbf{Time To The NDB} = \frac{60 \times \text{Minutes Flown Between Bearings}}{\text{Degrees Of Bearing Change}}$$

$$= \frac{60 \times 8}{14}$$

$$= \underline{\text{34 minutes}}$$

$$\textbf{Distance To The NDB} = \frac{\text{TAS/GS} \times \text{Minutes Flown Between Bearings}}{\text{Degrees Of Bearing Change}}$$

$$= \frac{140 \times 8}{14}$$

$$= \underline{\text{80 Nautical Miles}}$$

WORKSHEET 2

ADF/NDB

1. Variations of signal strength in NDB receivers known as fading indicates the presence of:

    a. Mountain or terrain effect;
    b. Reflection from thunderstorms;
    c. Night effect.

2. The accuracy of ADF bearings is affected by precipitation static because:

    a. The NDB transmission refracts as it passes through rain;
    b. Static produced by thunderstorms giving heavy rain attracts the ADF needle;
    c. Electro-magnetic fields produced when rain strikes an aircraft reduce the signal to noise ratio giving a broad null.

3. To hear the ident of an A1A NDB signal it is necessary to select:

    a. BFO ON;
    b. BFO OFF;
    c. ADF or BRG.

4. The ident signal of an A2A NDB signal is transmitted by ON/OFF keying of the:

    a. Carrier wave;
    b. Amplitude modulated tone;
    c. Frequency modulated tone.

5. To double the range of an NDB the power must be increased by a factor of:

    a. 2;
    b. 4;
    c. 8.

6. The ICAO NDB frequency band is:

    a. 200 KHz to 500 KHz;
    b. 200 KHz to 800 KHz;
    c. 200 KHz to 1750 KHz.

7. To determine the ADF bearing the aerial/aerials used are:

    a. The loop aerial only;
    b. The sense aerial only;
    c. Both the loop and the sense aerials.

8. To tune the ADF receiver to an NDB the aerial/aerials used are:

   a. The sense aerial only;
   b. The loop aerial only;
   c. Both the loop and the sense aerials.

9. The locator NDB type of emission recommended by ICAO is A2A because:

   a. The signal is more stable than A1A;
   b. The signal is less affected by night effect;
   c. The ADF needle does not wander during transmission of the ident.

10. A coastline lies in a north/south direction. An aircraft over the sea heading 360T receives an ADF bearing of 230 relative. The true bearing of the aircraft will be:

    a. Less than 050°;
    b. 050°;
    c. Greater than 050°.

11. Aircraft heading 225°M, ADF RMI is reading 090°. The quadrantal error of this bearing is:

    a. Maximum;
    b. Zero;
    c. Proportional to the Sine of the heading times the signal strength.

12. An aircraft is maintaining track outbound from an NDB with a constant relative bearing of 184°. To return to the NDB the relative bearing to maintain is:

    a. 356°;
    b. 000°;
    c. 004°.

13. At 1000Z an aircraft is overhead NDB PE en-route to NDB CT on a track of 075°M and maintaining a heading of 082°M. At 1029Z NDB PE bears 176° relative and NDB CN bears 353° relative. The heading to steer at 1029 to reach NDB CT is:

    a. 078°M;
    b. 079°M;
    c. 081°M.

14. The result of flying towards a NDB maintaining a 000° relative bearing with a crosswind is:

    a. The heading remains constant;
    b. The aircraft curves to the downwind of the NDB;
    c. The aircraft's track curves to the upwind side of the NDB.

15. A radio wave increases speed when crossing the coast, leaving the land and passing over the sea. When this happens:

    a. The frequency changes;
    b. The wavelength changes;
    c. No change in either.

16. At 1600Z NDB SL bears 091° relative by ADF. At 1604Z NDB SL bears 103° relative by ADF. If heading is altered at 1604Z to fly direct to SL, the ETA at TAS 150 kts will be:

    a. 1616Z;
    b. 1620Z;
    c. 1624Z.

17. The inbound track to NDB GDV is 075°T, Variation 10°W and the Drift 7°Right. The relative bearing to maintain on the radio compass to reach GDV is:

    a. 353°R;
    b. 000°R;
    c. 007°R.

18. The inbound track to NDB GDV is 075°T, Variation 10°W and the Drift 7°Right. The magnetic heading to steer to reach GDV is:

    a. 078°M;
    b. 085°M;
    c. 092°M.

19. The inbound track to NDB GDV is 075°T, Variation 10°W and the Drift 7°Right. The RMI ADF bearing to maintain to reach GDV is:

    a. 085°;
    b. 078°
    c. 092°.

20. An aircraft leaves NDB ABC, track 075°M, and Drift 6° Left. NDB XYZ bears 235° relative from the aircraft. What bearings from both NDBs would be shown on the RMI?

    a. 255° & 316°;
    b. 261° & 316°;
    c. 255° & 136°.

21. An aircraft is maintaining track outbound from an NDB with a constant relative bearing of 174°. To return to the NDB the relative bearing to maintain is:

    a. 354°;
    b. 000°;
    c. 006°.

22. At 1800Z an aircraft is overhead NDB AB en-route to NDB RK, Track 315°M and Heading 307°M. At 1829Z NDB AB bears 183° relative and NDB RK bears 006° relative. The heading to steer at 1829Z to reach NDB RK is:

    a. 310°M;
    b. 313°M;
    c. 316°M.

23. The modern ADF uses:

    a. A horizontal crossed loop aerial with an orthogonal pair of coils wound on a ferrite core fed to a goniometer;
    b. A horizontal crossed loop aerial with an orthogonal pair of coils wound on a ferrite core fed to a goniometer and combined with a signal from a sense aerial'
    c. A pair of coils, which rotate about a ferrite core, combined with a signal from a sense aerial.

24. An aircraft heading 040°M has an ADF reading of 060° R. The heading to steer to intercept the 120° track inbound to the NDB at 50° is:

    a. 050°M;
    b. 060°M;
    c. 070°M.

25. An aircraft heading 040°M has an ADF reading of 060°R. The alteration of heading required to intercept the 120° track inbound to the NDB at 50° is:

    a. 020° Right;
    b. 030° Right;
    c. 040° Right.

26. An aircraft heading 040°M has an ADF reading of 060° R and must intercept the 120°M track inbound to an NDB at 50°. The Relative bearing of the NDB that confirms the track interception is:

    a. 050° R;
    b. 060° R:
    c. 080° R.

27. An aircraft heading 325°M has an ADF reading of 330° R. The heading to steer to intercept the 280° track inbound to the NDB at 50° is:

    a. 310°M;
    b. 320°M;
    c. 330°M.

28. An aircraft heading 100°M has an ADF reading of 210° R. The alteration of heading required to intercept the 340° track inbound to the NDB at 60° is:

    a. 170° Right;
    b. 170° Left;
    c. 180° Left or Right.

29. An aircraft heading 200°M has an ADF reading of 160° R. The heading to steer to intercept the 150° track inbound from the NDB at 30° is:

    a. 110°M;
    b. 120°M;
    c. 130°M.

30. An aircraft heading 200°M has an ADF reading of 160° R and is to intercept the 150°M track outbound from an NDB at 30°. The relative bearing of the NDB that confirms track interception is:

    a. 210° R;
    b. 220° R;
    c. 230° R.

31. An aircraft heading 130°M has an ADF reading of 190° R. The heading to steer to intercept the 170° track outbound from the NDB at 30° is:

    a. 190°M;
    b. 200°M;
    c. 210°M.

32. An aircraft heading 130°M has an ADF reading of 190° R. The alteration of heading required to intercept the 170° track outbound from the NDB at 30° is:

    a. 50° Right;
    b. 60° Right;
    c. 70° Right.

33. An aircraft heading 130°M has an ADF reading of 190° R. The relative bearing of the NDB that will confirm interception of the 170° track outbound from the NDB at 30° is:

    a. 140° R;
    b. 150° R;
    c. 160° R.

34. An aircraft heading 135°M with 13° Right drift intercepts the 082°M track outbound from an NDB. The relative bearing of the NDB that confirms track interception is:

    a. 122° R;
    b. 127°R;
    c. 132°R.

35. An aircraft is flying a constant heading with 8° Right drift and is making good a track parallel to the centreline of an airway, but 5 nm off to the left of the centreline. The ADF reading of an NDB on the airway centreline 42 nm ahead of the aircraft is:

    a. 015° R;
    b. 011° R;
    c. 002° R.

Chapter 6

VHF Omni-Directional Radio Range (VOR)

VOR is the primary navigation radio in the aircraft. It does not suffer from the errors that affect the ADF such as static, night effect, or coastal refraction and can be used at any time during the flight. VOR radio stations are aligned to magnetic north using the variation at the station, so remember to use station variation when converting information form a VOR to true information for a map. The information for the VOR is calculated at the station and is sent to the aircraft where it is displayed to the pilots on one of three indicators i.e. the CDI, RMI and HSI. Information from the VOR station is represented by the term Radial, Bearing, QDR and Course. VOR stations can be co-located with a DME station to give the pilots bearing and distance information.

Summary for VOR Navigation

Frequency

VOR operates in the VHF band form 108 MHz to 117.95 MHz. There are 150 channels available and 108 MHz is used for test purposes. The VOR frequency band is split into two parts from 108 MHz to 112 MHz and they are as follows:

- VOR all the even, first decimal values i.e. 108.20
- ILS all the odd, first decimal values i.e. 108.30

Above 112 MHz all the frequency values are VOR only.

Transmission

The VOR radio station transmits a horizontally polarised signal, which is not affected by static noise, as static is normally vertically polarised.

Range of the VOR Station

There are different types of VOR stations i.e. terminal VOR TVOR, VORTAC, which is a VOR and TACAN station co-located, and TACAN that is a military station which will only give distance but no bearing information. The range of the station is approximately 200 nautical miles.

Emission of a VOR Station

The emission for the VOR transmitter is A9W

Summary for VOR Navigation

Identification of a VOR Station

VOR stations transmit a three letter Morse Identification Code every ten seconds. Some VOR have voice identification and ATIS or Automatic Terminal Information Service. Do not use the VOR if it does not identify.

Accuracy of a VOR Station

The VOR indicator should not display an error of greater than 4º. This error is made up of 1º from the transmitter or radio station and 3º from the aircraft equipment or receiver.

Aircraft Equipment

VOR Receiver

The VOR receiver is used to display the navigation information from the VOR station on the indicators for the pilots. It compares the phase difference of the two signals sent from the VOR station and determines the bearing or radial that the aircraft is on. The receiver then compares what radial is selected by the pilot and shows the deviation left or right of the aircraft from the selected radial. The receiver will also send information to the To / From flag on the indicator.

VOR Antenna

The VOR antenna is a horizontally polarised di-pole antenna. It is also used for the ILS localiser as the two radio navigation units are in the same frequency band. The antenna is usually mounted in the vertical stabiliser.

VOR Antenna

Course Deviation Indicator CDI

This is one of the indicators for the VOR. This indicator is used to indicate the deviation left or right of a selected radial.

Radio Magnetic Indicator RMI

This indicator is used as in the ADF to indicate where the station is i.e. points toward the station.

Principal of Operation of the VOR

The principal of operation of the VOR is bearing determination by means of phase comparison. The VOR station transmits two signals called the Reference Signal and the Variable Signal on the same carrier frequency. The receiver in the aircraft compares the phases of these two signals. Once the phase angle is compared the bearing or radial from the station is determined and displayed on the VOR indicator.

Reference Signal

The Reference Signal is defined as:

- The Reference Signal is an Omni-Directional Continuous Wave.
- It carries the 9960 Hz modulation.
- The signal if Frequency Modulated.

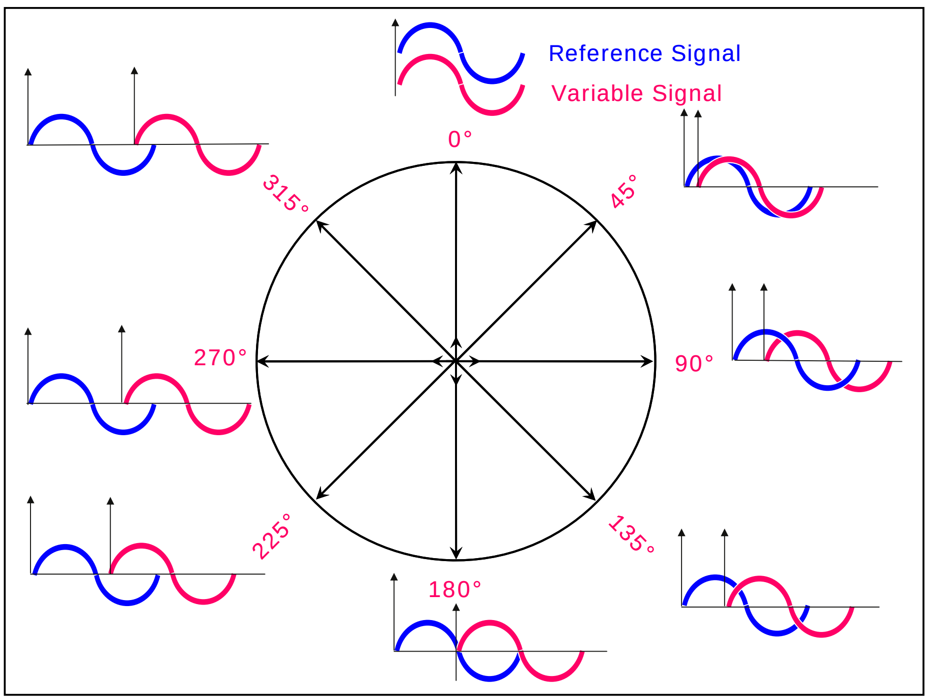
Variable Signal

The Variable Signal is defined as:

- The Variable Signal is Directional.
- It rotates at 1800 rpm or 30 times a second and is called a Limacon.
- The directional signal is apparently Amplitude Modulated.

Principal of Operation of the VOR

The receiver in the aircraft receives these two signals, compares the phase angle between them and then determines the bearing or radial from the station. The phase angle that is compared is also equal to the radial that the aircraft is on. Zero phase angle is arranged to be in the same position as magnetic north. The information is thus a magnetic bearing from the station. This information is then sent to the indicators to display navigation information to the pilots.



Now that the principal of operation has been discussed we will look at how the Course Deviation Indicator and the Radio Magnetic Indicator work. The HIS or Horizontal Situation Indicator is not discussed in this chapter.

Course Deviation Indicator CDI

Omni Bearing Selector or OBS

The OBS is used to set or select the required radial to fly. The selected radial is always displayed in the display window.

TO / FROM Flag or Indicator

The TO / FROM flag indicates whether the pilot has selected a radial that will take him toward the VOR station or whether the selected radial will take the pilot away from the VOR station. The TO / FROM flag does not indicate whether the pilot is flying toward the VOR station or away from the VOR station. The TO / FROM flag does not sense the heading of the aircraft. This must be crosschecked by the pilot.

Course Deviation Bar or Needle

The LEFT / RIGHT deviation bar is a command instrument i.e. fly toward the bar or follow the bar. If the bar is on the left side of the indicator the pilot must turn left. If the bar is in the centre of the instrument the aircraft is on the selected radial or on the reciprocal radial, depending on the TO / FROM flag.

Angular Dot Calibration Scale

The dots on the indicator represent the angular displacement in degrees from the selected radial. Indicators have five dots, four dots and two dots. The full-scale deflection from the centre of the scale to the last dot is always 10ºdegrees for a VOR.

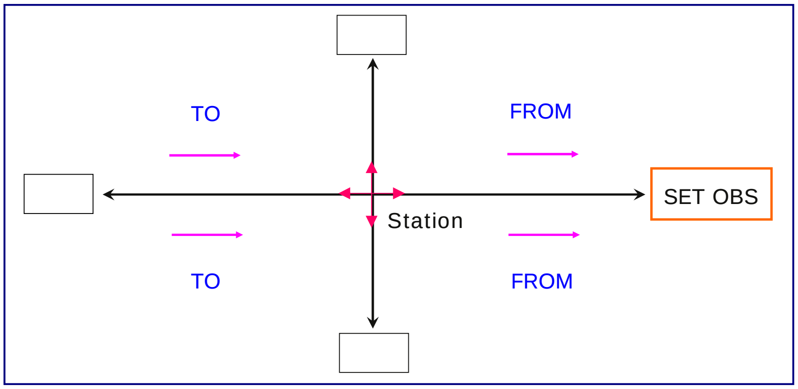
Rules for CDI Operation

- Remember that the CDI is not heading sensitive and that the correct heading of the aircraft must be checked by the pilot.
- The aircraft heading must be within 90º either side of the selected radial or reverse sensing will occur.
- As a rule for the TO /FROM flag, if the aircraft is on the same side of the station as the selected radial the FROM flag will be shown. If the aircraft is on the opposite side of the station as the selected radial, the TO flag will be shown.
- VOR is a magnetic instrument so variation at the station must be used to convert the magnetic information to true information for map work.
- The VOR station does not use a compass to calculate any information so no deviation is used in any calculation.

VOR CDI Calculations

When doing the following calculations a sketch must be used to orientate the given information correctly. The following steps can be used to solve the calculations:

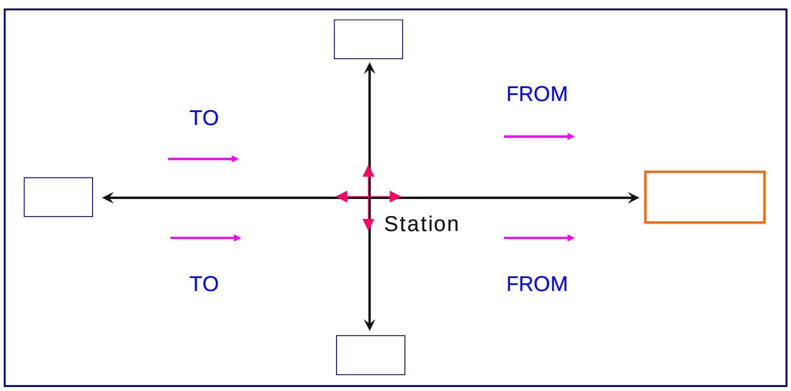
- Draw the sketch. Use the same sketch for all the calculations.
- The set or selected radial or OBS is inserted into the space on the right of the sketch.
- The compass numbers are then orientated by adding 90º each time.
- Finally using the information given solve the calculation.



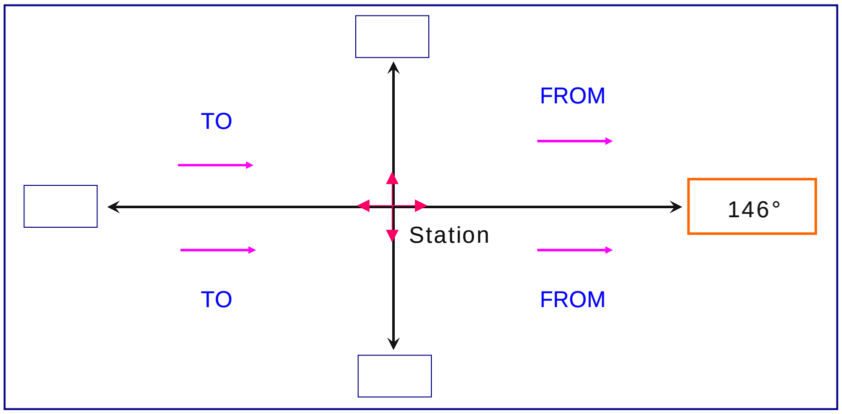
VOR CDI Calculations Example No 1

An aircraft is heading 340º at 30 nautical miles from a VOR station on a bearing of 142º magnetic. The pilot has selected the 146º magnetic bearing on the OBS. What is the indication on a 5 dot VOR CDI?

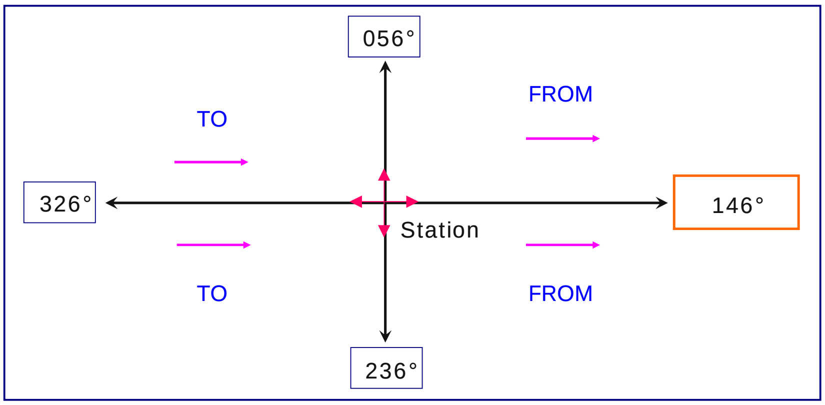
Step No 1: Draw the Sketch



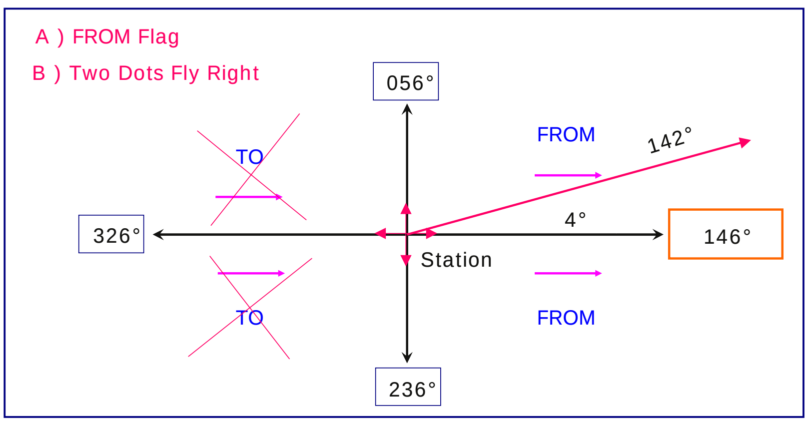
Step No 2: Insert the Selected OBS



Step No 3: Orientate the Compass Headings

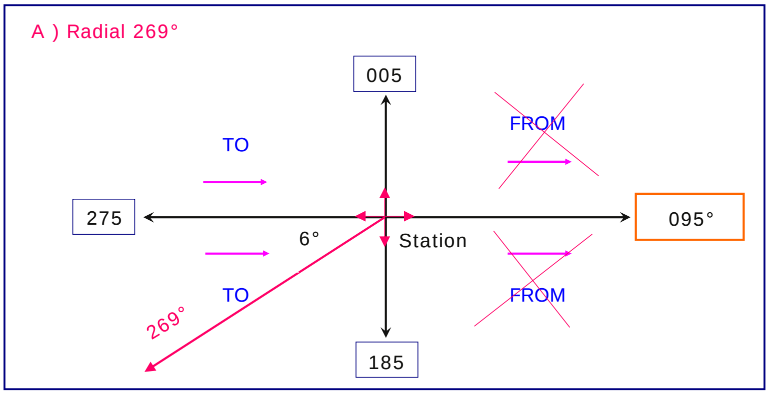


Step No 4: Solve Using the Given Information



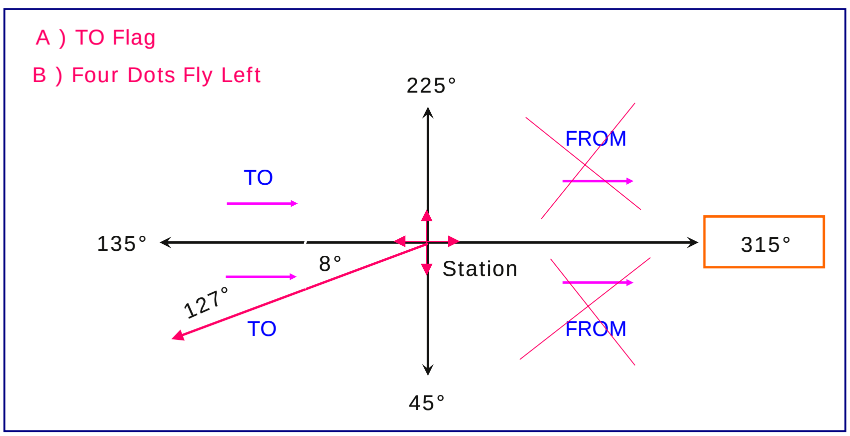
VOR CDI Calculations Example No 2

An aircraft is heading 065ºmagnetic and has the OBS set at 095º magnetic. The LEFT / RIGHT needle of a 5 dot CDI is showing 3 dots left of centre with a TO flag indicated. The aircraft is on what radial?



VOR CDI Calculations Example No 3

An aircraft is heading 045º magnetic and is on a true bearing of 135º. Variation at the station is 8º east; variation at the aircraft is 10º east. If the OBS is set to 315º what would the indication on a 5 dot CDI be?



Radio Magnetic Indicator RMI

The Radio Magnetic Indicator is the second instrument that can show VOR information in the Commercial Radio syllabus. The operation of the RMI is the same as for the ADF in the following way:

- The compass card shows the aircraft compass heading under the lubber line.

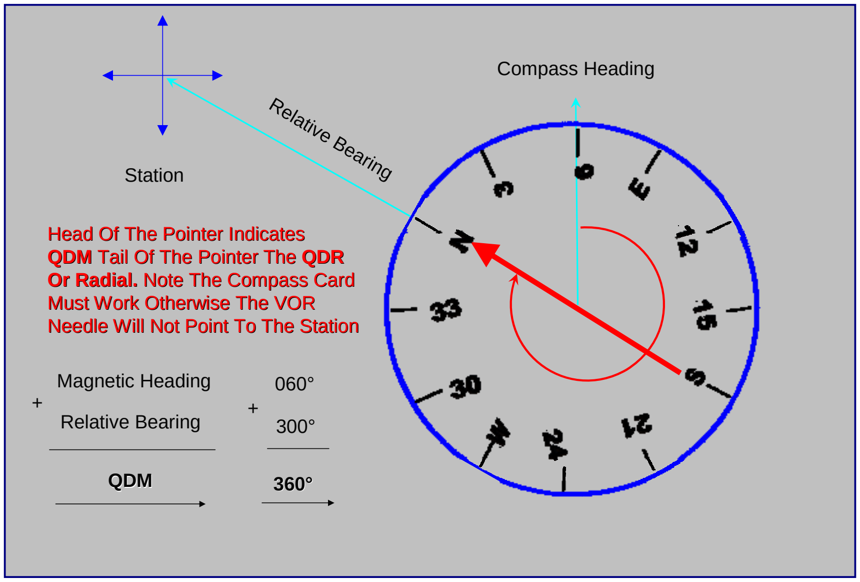
- The VOR pointer shows the angle measured from the nose of the aircraft to the VOR station i.e. the relative bearing.

- Remember when working with a VOR to use the variation at the station to convert the magnetic information obtained to true information for map work. Deviation is not required as the VOR RMI automatically compensates for this error by means of a differential synchro.

The advantage of the RMI is that no calculation is required to be made by the pilot as the aircraft heading is displayed continuously. The head of the RMI pointer shows the QDM and the tail of the pointer shows the QDR. If the compass card were to become inoperative this would be shown by the red flag. In this case the VOR would still work but the differential synchro would not be reading the correct heading and the pointer would not point to the station.

Radio Magnetic Indicator Operation

As can be seen the VOR pointer points to the station i.e. relative bearing and the compass card shows the aircraft compass heading. As the pointer is superimposed on the card the head of the pointer shows the QDM and the tail show the QDR. The calculation is made automatically.



VOR Errors

Site Errors

These errors are caused by buildings, obstacles or uneven terrain at the location of the VOR station i.e where the VOR is sited.

Propagation Errors

Normally terrain in the path of the VOR signals at low altitude cause the signals to be reflected. These reflected signals and line-of-sight signals arrive at the aircraft receiver out of phase causing a distorted signal. This distortion causes the deviation bar to move from side to side, known as scalloping.

Interference Errors

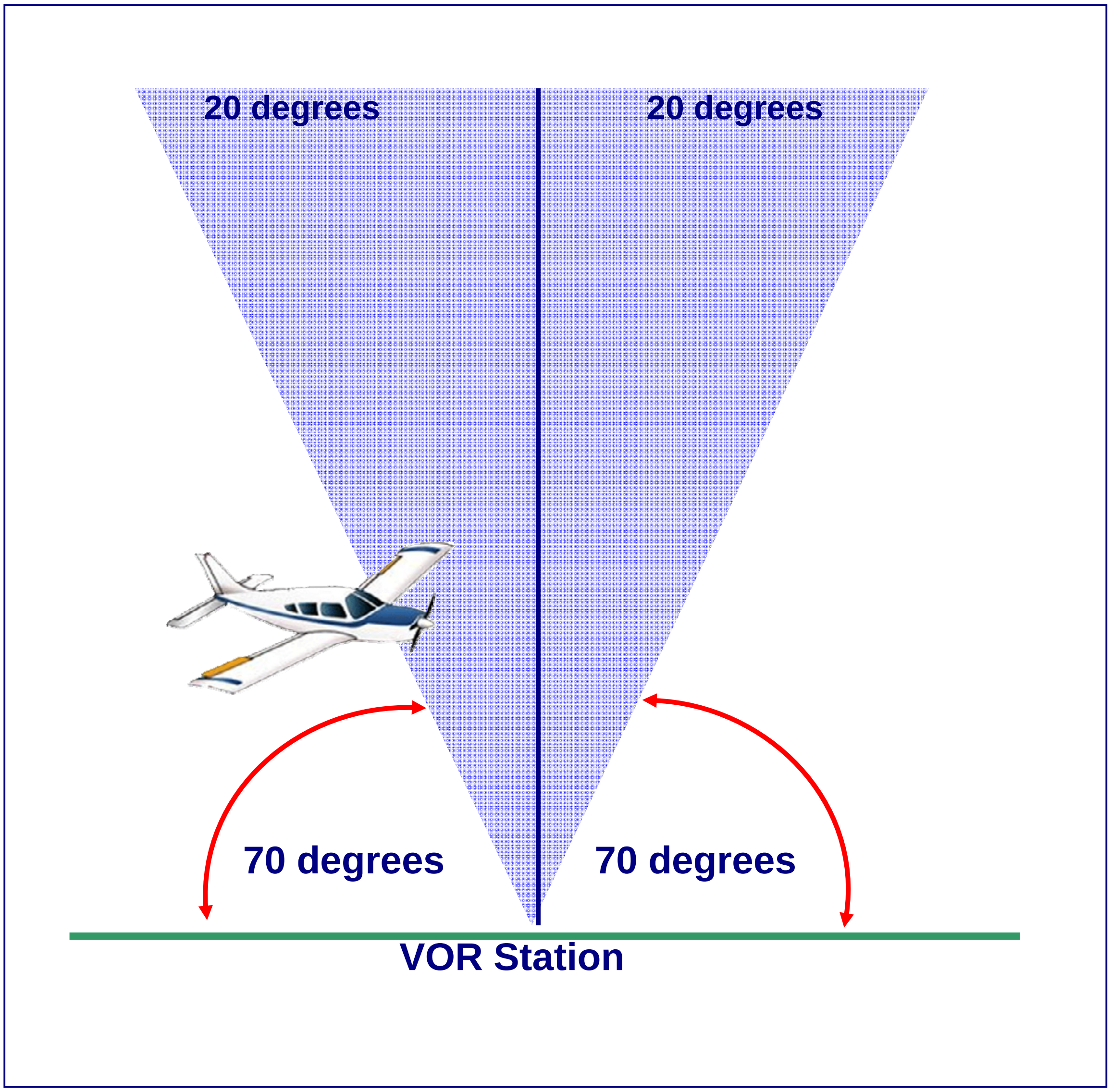
These errors are caused when two VOR stations transmitting on the same frequency are received by the aircraft at the same time by the same receiver.

Aircraft Equipment Errors

As seen before a total of 4º degrees error is allowed on the indicator. Only 1º degree is allowed for the VOR station and 3º degrees is allowed for the receiver. When working with a dual pointer RMI only 6º degrees is allowed between the two pointers.

Cone of Ambiguity Error

A VOR station transmits in the horizontal plane up to an angle of 70º degrees. This leaves an area of 20º degrees each side of the station where there is no signal. As an aircraft flies through this cone the receiver will not show any information. The higher the aircraft the larger the cone and the longer it will take to clear the area of ambiguity.



VOR Test Facility VOT

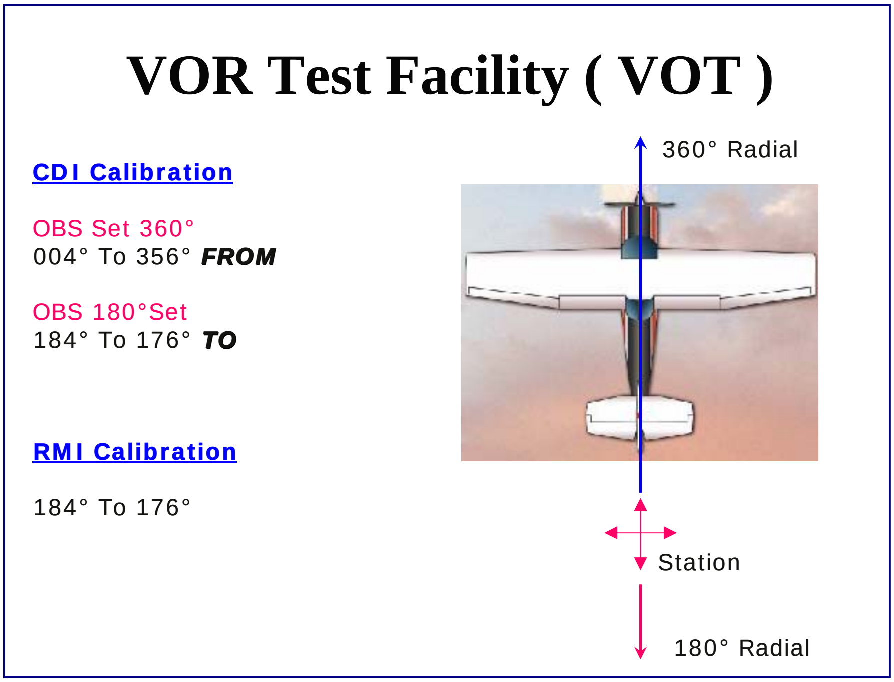
The VOT or VOR test facility is used to calibrate the aircraft equipment on the ground. The facility consists of a low power VOR situated behind the test pad aligned to transmit the 360º radial through the test pad as indicated in the drawing below. The aircraft is placed on the test pad and both the CDI and RMI are calibrated. The following information is required for the equipment to be serviceable:

Course Deviation Indicator CDI

- CDI central, an OBS reading of 356º degrees to 004º degrees with a FROM flag.
- CDI central, an OBS reading of 184º degrees to 176º degrees with a TO flag.

Radio Magnetic Indicator RMI

- RMI reading of 176º degrees to 184º degrees QDM.



Typical Exam Questions

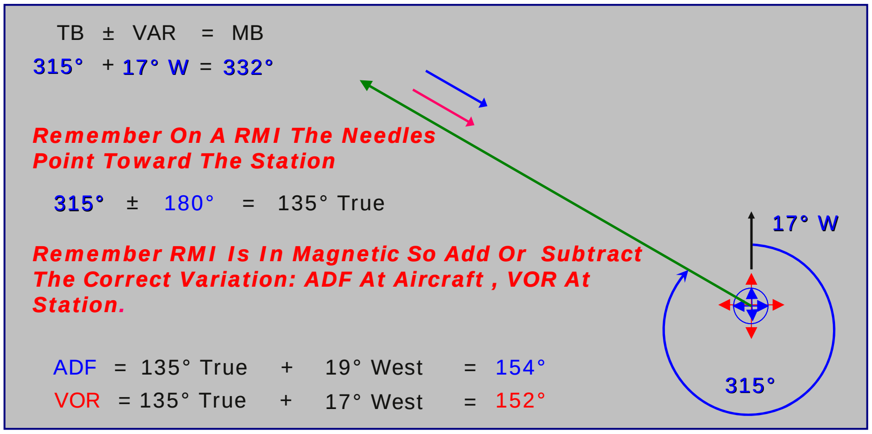
These are some of the more difficult questions in the Radio Aids syllabus:

- Twin Pointer VOR / ADF RMI.
- Max range of two VOR stations.
- 1-in-60 rule.
- Leading and lagging of two VOR signals.

Twin pointer VOR / ADF RMI

A VOR and a NDB are co-located on an aerodrome where the variation is 17 degrees west. An aircraft is flying where the variation is 19 degrees west on a magnetic bearing of 332 degrees from the VOR station. What are the VOR and ADF readings on a twin pointer RMI?

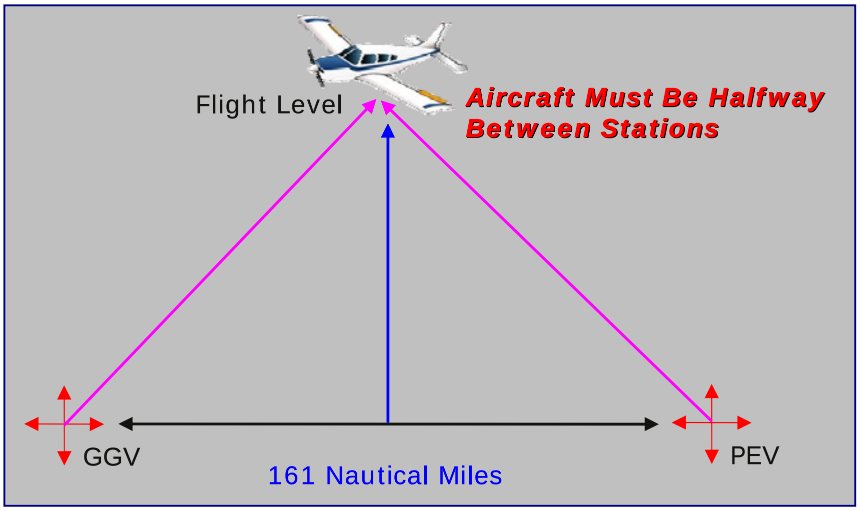
The easiest method to solve this question is to convert all the magnetic information into true information. Then solve the calculation using the RMI information and theory. And lastly because they ask for RMI information, apply the correct variation i.e. for VOR variation at the station and for ADF variation at the aircraft.



Range of Two VOR Stations

VOR GGV and PEV are 161 nautical miles apart. Both VOR stations are on the same frequency and are 200 feet above mean sea level. What is the minimum altitude that an aircraft would be able to receive both VOR stations at the same time?

This is a maximum theoretical range question and it is easily solved by using the formula in Chapter One. First make the sketch then use the formula to solve.



$$\text{Range (NM)} = 1.25 \times \sqrt{\text{RX Height In } \textbf{\textit{FEET}}} + 1.25 \times \sqrt{Tx \text{ Height In } \textbf{\textit{FEET}}}$$

$$80.5\ \text{NM} = 1.25 \times \sqrt{X\ Feet} + 1.25 \times \sqrt{200\ Feet}$$

$$80.5\ \text{NM} = 1.25 \times \sqrt{X\ Feet} + 1.25 \times 14.14$$

$$80.5\ \text{NM} = 1.25 \times \sqrt{X\ Feet} + 17.675$$

$$80.5\ \text{NM} - 17.675 = 1.25 \times \sqrt{X\ Feet}$$

$$\frac{62.825}{1.25} = \sqrt{X\ Feet}$$

$$\text{Flight Level} = 2526\ \text{Feet}$$

One-In-Sixty Rule

A VOR defines the centre of an airway 10 nautical miles wide. An aircraft at DME distance 180 nautical miles has a two dot fly left indication on a five dot CDI. What is the distance from the centre of the airway and how far is the aircraft outside the airway?

This question is solved using the One-in-Sixty rule i.e. if an aircraft has a track error of one degree then after flying for sixty miles the aircraft will be one nautical mile off track.

$$\frac{\text{Track Error}}{60} = \frac{\text{Distance Off}}{\text{Distance To Go}}$$

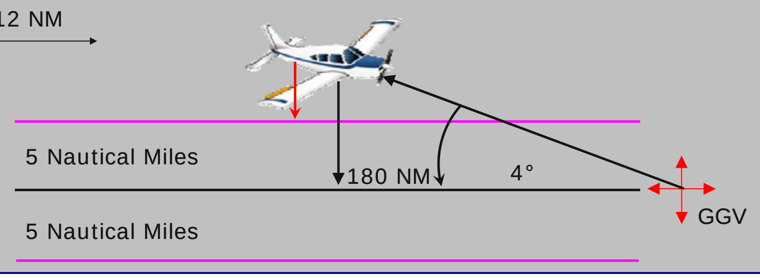
$$\frac{4°}{60} = \frac{\text{Distance Off}}{180\ \text{NM}}$$

$$\frac{720}{60} = \text{Distance Off}$$

$$= 12\ \text{NM}$$

A) Distance From Centre = 12 NM

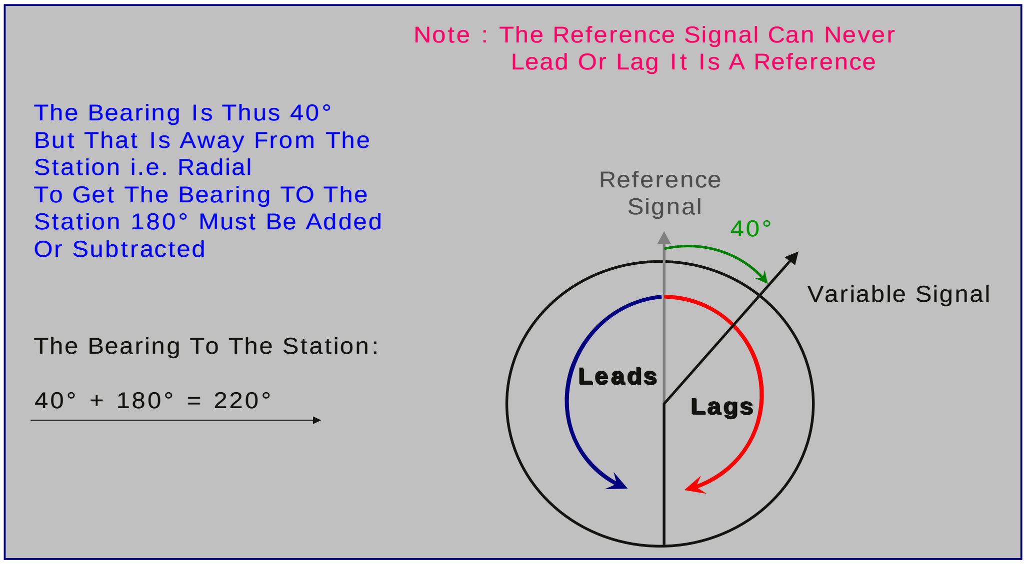
B) Distance From Boundary = 7 NM



Leading and Lagging of Two VOR Signals

The variable signal of a VOR lags the reference signal by 40 degrees. The bearing to the VOR is?

In this question remember that VOR bearings or radials are QDR's and are measured away from the station. If a bearing to the station is asked 180 degrees must be added to the bearing information to obtain a QDM or bearing toward the station.



WORKSHEET 3

VOR

1. The operational principle of VOR is bearing determination by:

   a. Frequency comparison;
   b. Wavelength comparison;
   c. Phase comparison.

2. The accuracy of VOR radials is better than:

   a. ±1°
   b. ±4°
   c. ±6°

3. The accuracy of VOR radials as determined by the aircraft's equipment if serviceable is:

   a. ±1°
   b. ±4°
   c. ±6°

4. A twin pointer RMI shows radials from a single VOR transmitter. The difference between the readings should not be greater than:

   a. 4°
   b. 6°
   c. 8°

5. The principle factors affecting accuracy of VOR radials as indicated by the aircraft's equipment are:

   a. Aircraft equipment error, site error, refraction error and propagation error.
   b. Propagation error, site error, aircraft equipment error and night effect.
   c. Site error, interference error, propagation error and aircraft equipment error.

6. VOR CDI indications in an aircraft may fluctuate by as much as ±6° and may be caused by:

   a. Certain propeller RPM or helicopter rotor speeds;
   b. Co-located DME transmissions;
   c. Quadrantal error.

7. A VOR ground station transmits a reference signal and a variable signal, the characteristics of which are:

   a. An omni-directional reference signal amplitude modulated at 30 Hz and a rotating 9960 Hz sub-carrier variable signal;
   b. An omni-directional reference signal which carries a 9960 Hz sub-carrier frequency modulated at 30 Hz and a rotating variable signal at 1800 RPM which gives an apparent 30 Hz amplitude modulation;
   c. A 9960 Hz sub-carrier reference signal amplitude modulated at 30 Hz and a rotating cardioid variable frequency modulated at 30 Hz.

8. The VOR frequency band is:

   a. 118 Mhz to 136 Mhz;
   b. 108 Mhz to 112 Mhz;
   c. 108 Mhz to 117.95 Mhz.

9. The datum of a Radio Magnetic Indicator (RMI) is:

   a. True north;
   b. Magnetic north;
   c. Compass north.

10. If the variable phase if a VOR transmission lags the reference signal by 40° the bearing of the VOR is:

    a. 220°;
    b. 040°;
    c. 320°.

11. If a malfunction of the main VOR transmitter occurs and is shut down, a standby transmitter may be brought into operation. It takes time for the signal to stabilise and the bearings may be inaccurate. Aircraft are warned of possible inaccuracies by:

    a. The VOR nor transmitting the reference signal;
    b. The VOR not transmitting the ident signal;
    c. A voice warning that the VOR is not to be used.

12. An aeroplane is inbound to a VOR on radial 065°. VOR variation is 3°W and aircraft variation is 5°W. If drift is 4° Left the initial heading to maintain the radial is:

    a. 247°M;
    b. 249°M;
    c. 251°M.

13. An aircraft is on a true bearing of 090° from a VOR. Variation at the VOR is 10°W and variation at the aircraft is 8°W. The CDI left/right needle will be central when the OBS is set at:

    a. 100° FROM;
    b. 098° FROM;
    c. 100° TO.

14. VOR B is situated on radial 233°, 120 nms from VOR A. An aeroplane, G/S 300 kts, is approaching VOR A on radial 143°. At 0900Z the aeroplane is on radial 098° from B. If the aeroplane alters heading at 0900Z for VOR B the ETA at B will be:

    a. 0928Z;
    b. 0934Z;
    c. 0940Z.

15. To prevent inaccurate bearings being transmitted during maintenance a VOR station will:

    a. Not transmit the variable signal;
    b. Transmit a voice warning;
    c. Remove the ident signal.

16. Full scale deflection of the left/right needle on a VOR CDI means an aircraft is more than:

    a. 2½° from the selected radial or its reciprocal;
    b. 5° from the selected radial or its reciprocal;
    c. 10° from the selected radial or its reciprocal.

17. An aircraft heading 065°M has the VOR CDI OBS set at 095°. The left/right needle of a 5 dot CDI is 3 dots left of centre with TO indicated. The aircraft is on radial:

    a. 101°;
    b. 269°;
    c. 281°.

18. A VOR and a NDB is co-located on an aerodrome where the variation is 17°W. An aircraft is flying where the variation is 19°W on a true bearing of 315° from the aerodrome. The VOR and ADF bearings on a twin pointer RMI would be:

    a. VOR 152° ADF 154°;
    b. VOR 152° ADF 152°;
    c. VOR 154°; ADF 152°.

19. A VOR and a NDB is co-located on an aerodrome where the variation is 12°W. An aircraft is flying where the variation is 10°W on a true bearing of 215° from the aerodrome. If compass deviation is 2°W, the VOR and ADF bearings on a twin pointer RMI would be:

    a. VOR 047° ADF 045°;
    b. VOR 047° ADF 047°;
    c. VOR 045°; ADF 045°.

20. An aircraft heading 045°M, is on a true bearing of 135° from a VOR, variation 8°E. If the OBS were set at 315° the indication on a 5 dot CDI would be:

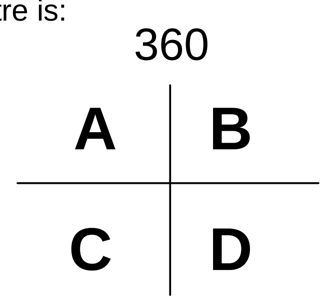
    a. TO 4 dots left;
    b. TO needle central;
    c. TO 4 dots right.

21. The maximum allowable tolerance of the OBS (CDI left/right needle centred) when checking a VOR receiver by means of a VOT is:

    a. 178° to 182° FROM;
    b. 176° to 184° TO;
    c. 356° to 004° TO;
    d. 350° to 002° FROM.

22. Four aircraft, A, B, C & D have their OBS set to 360°. The aircraft that would have FROM indicated and the left/right needle left of centre is:

    a. A;
    b. B;
    c. C;
    d. D.



23. When the VOR OBS meter indicates TO and the left/right deviation needle of the CDI is central, the aircraft will be:

    a. Inbound to the VOR;
    b. Outbound from the VOR;
    c. On the radial shown by the course selector;
    d. On the reciprocal of the radial shown by the course selector.

24. When the course selector is set to 105°, the left/right needle is centred and the TO/FROM indicator shows TO it means:

    a. The aircraft bears 105°M from the VOR;
    b. The magnetic track to the VOR is 105°;
    c. The true bearing of the aircraft from the VOR is 105°;
    d. The true track to the VOR is 105°.

25. The VOR reference signal is:

    a. A rotating signal Amplitude Modulated at 30 Hz;
    b. A Limacon;
    c. A 9960 Hz sub-carrier Amplitude Modulated at 30 Hz.

26. The VOR directional signal is:

    a. A rotating signal Frequency Modulated at 30 Hz;
    b. A Limacon;
    c. A 9960 Hz sub-carrier Amplitude Modulated at 30 Hz.

27. VOR GGV and VOR PEV are 161 nms apart. Both VOR's are 200 ft AMSL. The minimum altitude that an aircraft would be able to receive both VOR's is:

    a. 4176 ft;
    b. 3289 ft;
    c. 2526 ft.

28. An aircraft bears 045°T from a VOR (variation 13°E). The OBS settings that would centre the left/right needle of a CDI would be:

    a. 045° and 225°;
    b. 058° and 238°;
    c. 032° and 212°.

29. Pointer 1 of an RMI is tuned to a VOR. Pointer 2 is tuned to a co-located NDB. The two pointers will:

    a. Point exactly to the same direction;
    b. Point in different directions due to the difference in variation between the aircraft and the transmitters;
    c. Point in different directions because VOR uses the VHF band and the NDB uses the LF/MF band.

30. An aircraft heading 280°M is on a bearing of 090°M from a VOR. The OBS setting that should be selected in order to centralise the left/right deviation needle with TO indicated is:

    a. 280°;
    b. 270°;
    c. 100°.

31. An aircraft heading 220°M has the OBS set at 030°. A 5 DOT CDI shows the left/right needle 4.5 dots right of centre with FROM indicated. The aircraft is on radial:

    a. 021°;
    b. 039°;
    c. 201°.

32. An aircraft is maintaining radial 090° outbound from VOR XYZ. After flying 35 minutes the aircraft returns to NDB XYZ, which is co-located with VOR XYZ. Aircraft variation is 22°W and VOR variation is 20°W. The QDM to the NDB is:

    a. 280°;
    b. 270°;
    c. 272°.

33. An aircraft heading 320°M is 45 nms from VOR/DME NEV on radial 136°. If 140° is selected on the OBS and FROM appears in the window, the left/right indication on a 5 DOT CDI would be:

    a. 2 Dots Right;
    b. 2 Dots Left;
    c. Central.

34. An aircraft is established on radial 135° inbound to VOR ABC. VOR CPL is 120 nms from VOR ABC on radial 225°. At 1015Z the aircraft receives QDM 270° from VOR CPL. TAS is 300 kts with no wind. What is the ETA at VOR CPL if heading is altered at 1015Z?

    a. 1039Z;
    b. 1049Z;
    c. 1059.

35. An aircraft passes overhead VOR/DME EPS at 0913Z, maintaining radial 252°, heading 244°M, TAS 230 kts and variation 15°W. At 0928Z VOR/DME EPS indicates DME 63 nms. What is the W/V?

    a. 080/40;
    b. 095/40;
    c. 110/40.

36. Two VOR stations are to be sited on the centreline of an airway 10 nms wide. If a bearing accuracy of 5° is required from the two stations, the maximum distance apart that the two transmitters could be sited is:

    a. 120 nms;
    b. 180 nms;
    c. 240 nms.

37. The maximum range that an aircraft flying at FL 210 would receive a VOR (800 ft AMSL) is:

    a. 216 St Mile;
    b. 228 nms;
    c. 400 kms.

38. A VOR/DME define the centreline of an airway 10 nms wide. An aircraft at 180 nms DME distance out has a 2 Dot fly left indication on a 5 DOT CDI with the airway centreline radial set. The distance of the aircraft from the boundary of the airway is:

    a. 2 nms;
    b. 7 nms;
    c. 12 nms;
    d. 17 nms.

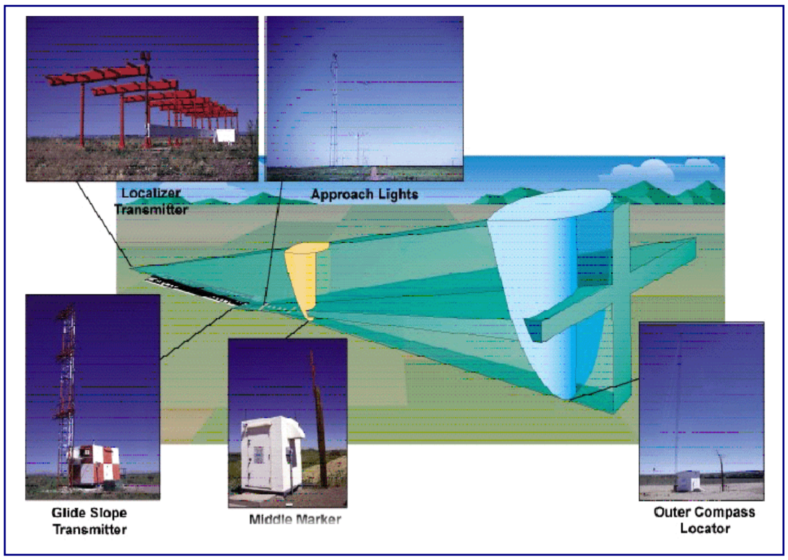
39. The VOR CDI OBS is set at 050° with the left/right needle central but the TO/FROM indicator is unserviceable. If the OBS is changed to 060° and the left/right needle deflects to the right, the aircraft is on:

    a. 050° radial flying away or towards the VOR;
    b. 230° radial flying towards or away from the VOR;
    c. 230° radial with the heading having no influence.

Chapter 7

Instrument Landing System (ILS)

An Instrument Landing System (ILS) is used by the pilot to do an approach on to a runway in Instrument Meteorological Conditions (IMC). The aircraft is guided in both the horizontal or azimuth plane and the vertical plane. The Localiser component of the ILS is used to locate the centre line of the runway and is in the VHF radio frequency band. The Glide Slope is used to guide the aircraft in the vertical plane and is in the UHF radio band. The aircraft is flown either manually or on automatics to the decision height where the pilot will either complete a landing or execute a missed approach. A runway that is equipped with an ILS is called a Precision Approach Runway (PAR). Before an ILS approach is flown three components must be present. The pilot must have an Instrument Rating, the aircraft must be properly equipped with an ILS system and the airport must be equipped with serviceable ILS equipment. It must be noted to fly a Category II or Category III ILS the above components must be specifically certified by the local CAA. It must also be noted that it is an offence to go below decision height unless the required visual references are obtained.



Summary for an Instrument Landing System ILS

Frequency

- Localiser frequencies are in the VHF frequency band and are from 108 MHz to 111.95 MHz. All the odd, first decimals.

- Glide Slope frequencies are in the UHF frequency band and are from 329.3 MHz to 335 MHz

Transmission

The Localiser frequencies are selected by the pilot on the VHF navigation receiver and the Glide Slope frequencies are automatically paired. These frequencies are said to be frequency paired.

Identification

The ILS system is identified by a three letter Morse Code every 10 seconds. The Localiser frequency carries the identification code.

Emission of the ILS

The ILS has an A2A emission for the Localiser, Glide Slope and Marker Beacon transmitters.

Aircraft Equipment

ILS Receiver

The ILS receiver is used to select ILS frequencies, and send the information from the ground transmitters to the ILS indicator. The receiver works on the principal of Depth Modulation to determine the aircraft position with respect to the Localiser and Glide Slope beams. Only the Localiser frequency is selected on the receiver, the Glide Slope is frequency paired.

Course Deviation Indicator CDI

The CDI is also used to show ILS information. It has two deviation bars, one in the horizontal to indicate Glide Slope and one in the vertical to indicate Localiser. When VOR information is displayed the Glide Slope flag is shown indicating that the Glide Slope in not available. It must be noted that the OBS selector has no effect in the indications when the ILS is used. The indicator is a command instrument; the pilot must follow the deviation bars. Some older indicators have a blue and a yellow marker on the faceplate. If the deviation bar is deflected to the left then the aircraft is in the blue sector. If the deviation bar is deflected to the right then the aircraft is in the yellow sector.

Components of the CDI

Angular Dot Calibration Scale

Localiser

- The dot scale represents the angular displacement in degrees from the Localiser. Indicators have either 5 dot, 4 dot or 2 dot scales. The full-scale deflection from the centre of the scale to the last dot is always 2.5 degrees for a Localiser.

Glide Slope

- The dot scale represents the angular displacement in degrees from the Glide Slope. The full-scale deflection from the centre of the scale to the last dot is always 0.7 degrees for a Glide Slope.

Components of the CDI

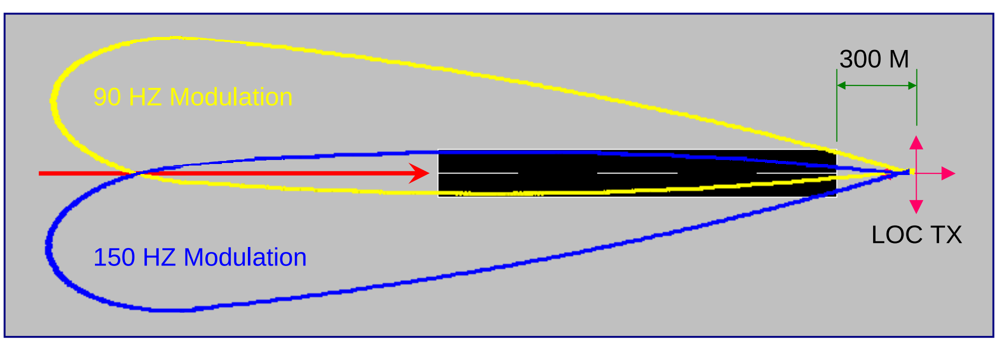
Angular Dot Calibration Scale

ILS Ground Equipment

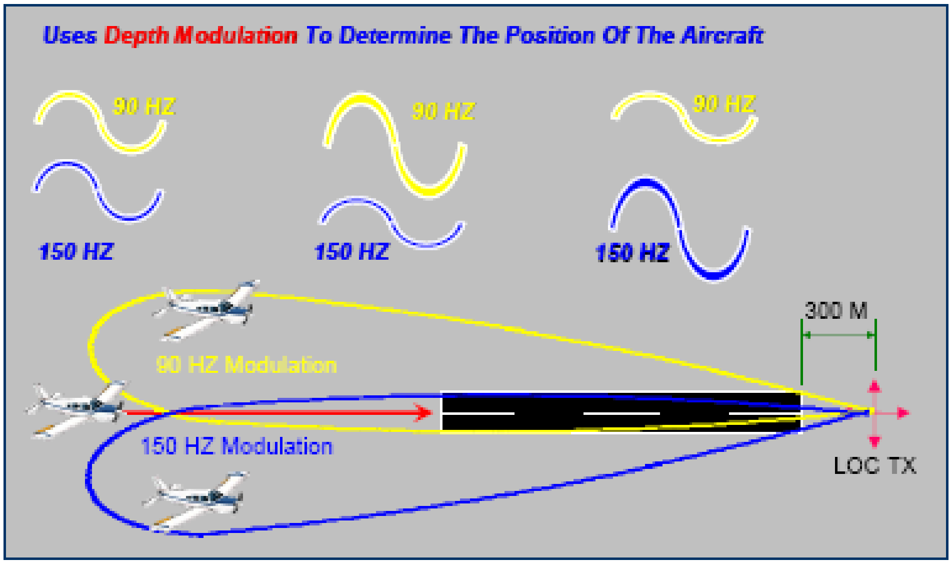
Localiser Transmitter

The Localiser Transmitter is situated on the centre line of the runway, approximately 300 meters upwind of the runway end threshold. The transmitter transmits two lobes or Amplitude Modulated signals in the horizontal plane. The signals are directional and the 150 Hz modulation is always on the right side of the runway as viewed from the pilot and is called the Blue Lobe. The 50 Hz modulation is always on the left of the runway as viewed from the pilot and is called the Yellow Lobe. The Localiser beam provides guidance in the azimuth or horizontal plane and is indicated by the vertical deviation bar on the CDI.

Localiser Transmitter

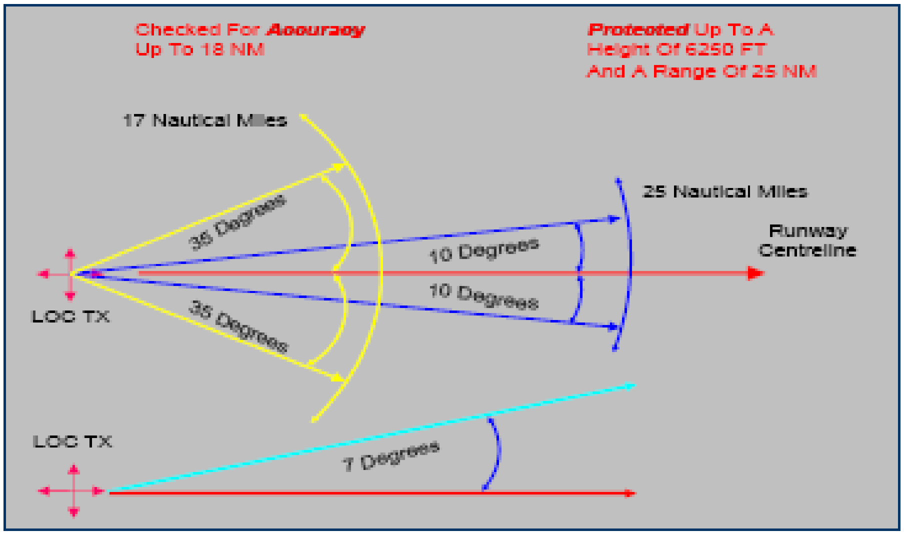


The Localiser uses the principal of Depth Modulation. If the aircraft is to the left of the runway then the receiver will receive a stronger signal from the Yellow Lobe and a weaker signal from the Blue Lobe. This difference will be indicated by a difference in the amplitude of the two modulations. This difference is sent to the indicator, which will show a fly right indication. The same principal of operation applies if the aircraft is to the right of the runway. The signal from the Blue Lobe is stronger and the deviation bar will deflect to the left.



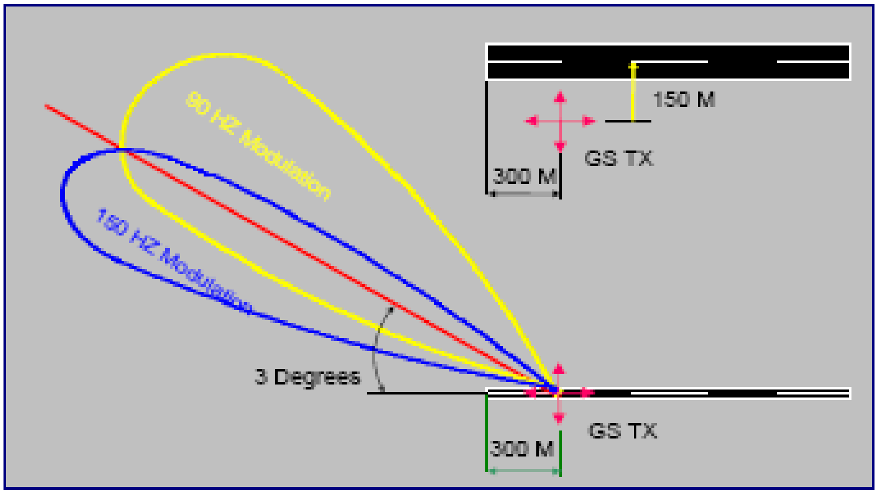
Localiser Coverage Area

This is the area that the radio signal will cover when transmitted. The Localiser is directional and cannot be used when the aircraft is outside this area for Localiser navigation.



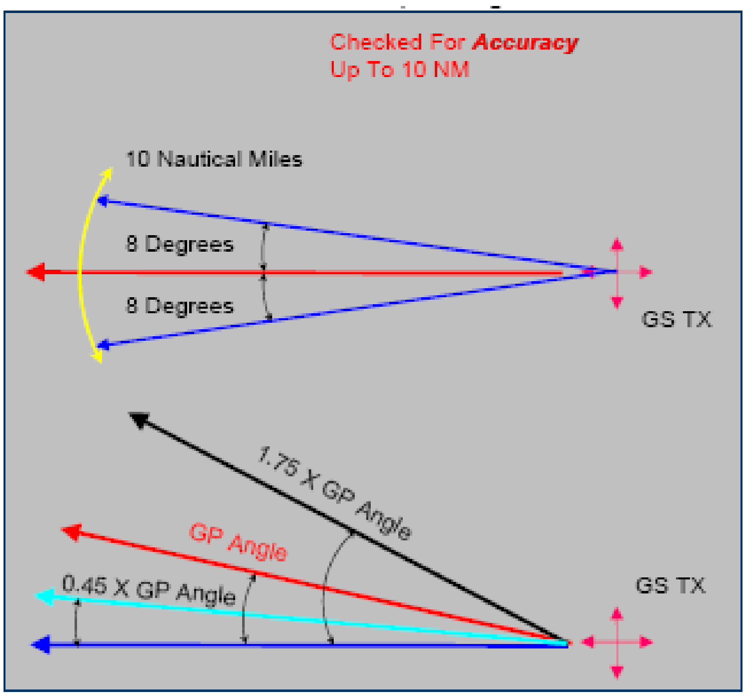
Glide Slope Transmitter

The Glide Slope Transmitter is situated approximately 300 meters upwind from the landing threshold and approximately 150 meters from the centre line of the runway. The Glide Slope Transmitter transmits two lobes or Amplitude Modulated signals in the vertical plane. The signals are directional and the 90 Hz modulation or the Yellow Lobe is above the 150 Hz modulation or the Blue Lobe. The Glide Slope beam provides guidance in the vertical plane and is indicated by the horizontal deviation bar on the CDI. The Glide Slope beam is between 2 degrees and 4 degrees.



Glide Slope Coverage Area

This is the area that the radio signal will cover when transmitted. The Glide Slope is directional and cannot be used outside this area for Glide Slope navigation.

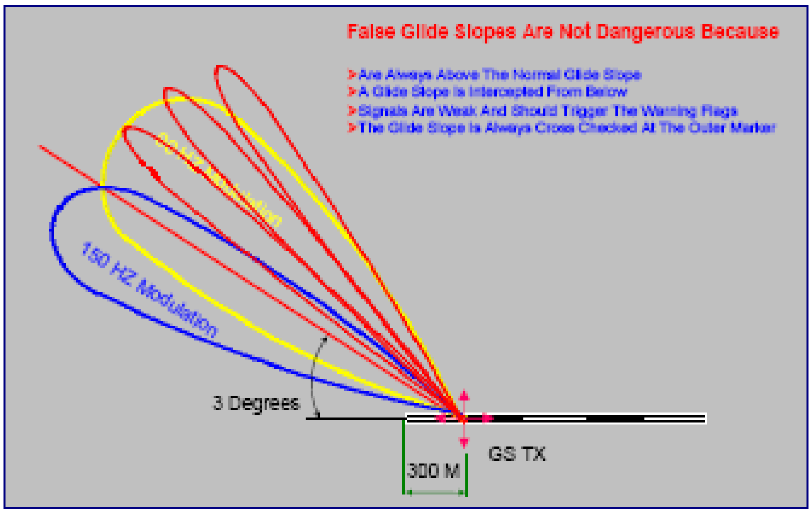


False Glide Slopes

False Glide Slopes are caused partly by the propagation errors of the Glide Slope aerials and starts to occur at approximately 6 degrees above the horizontal plane. False Glide Slopes are not dangerous because:

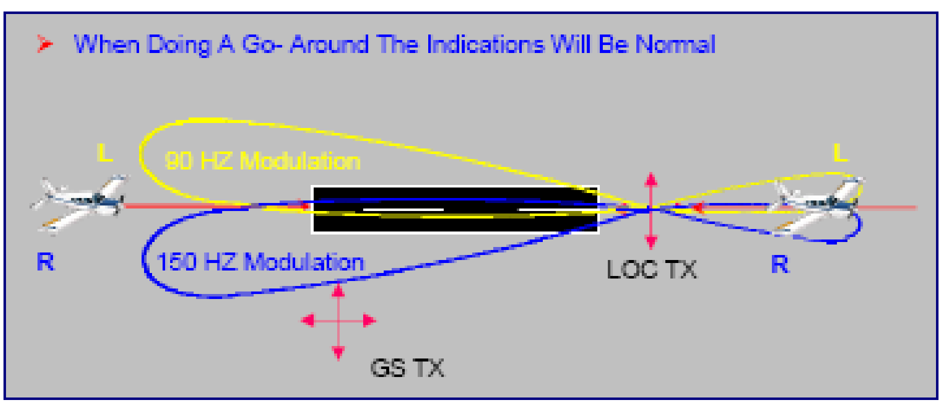
- A false Glide Slope is above the normal Glide Slope producing an abnormal rate of descent of the aircraft on that Glide Slope.
- An ILS is intercepted from below so as not to intercept a false Glide Slope.
- The signal strength of a false Glide Slope is weak and will show instrument flags.
- The ILS Glide Slope crossing height is checked at an outer marker and a false Glide Slope will be detected.

False Glide Slopes

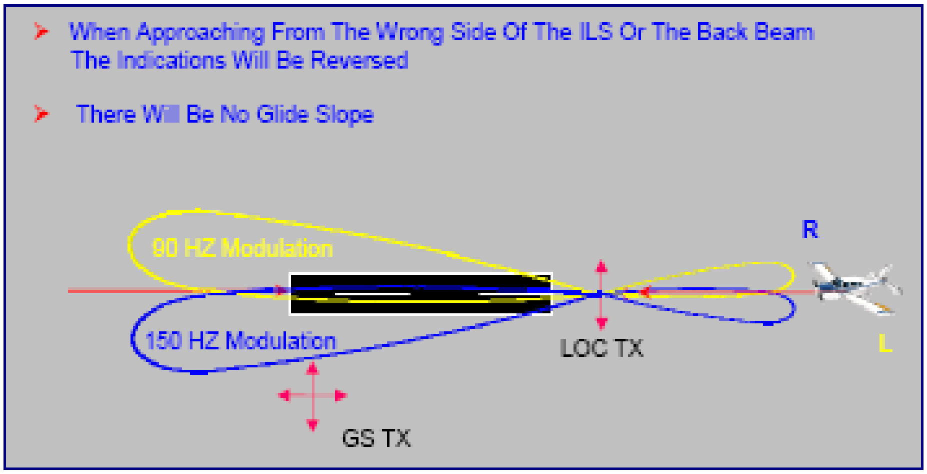


ILS Back Beam or Back Course

ILS Localiser aerials transmit lobes behind the aerial that have less signal strength but the same properties as the front beams. These Back Beams can be used to fly a back beam approach to the reciprocal runway or to fly an accurate runway track when taking off from an ILS equipped runway. Care must be taken when flying a Back Beam approach as there will be reverse sensing on the CDI and there will be no Glide Slope indications.

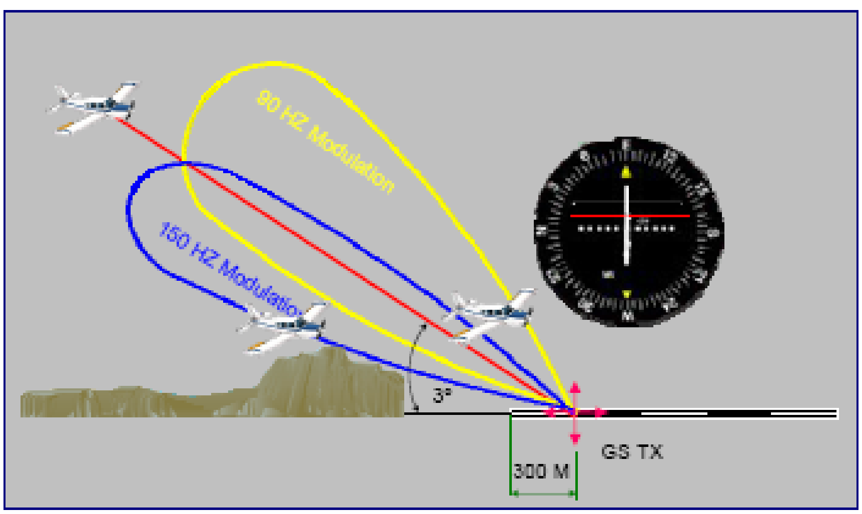


ILS Back Beam or Back Course



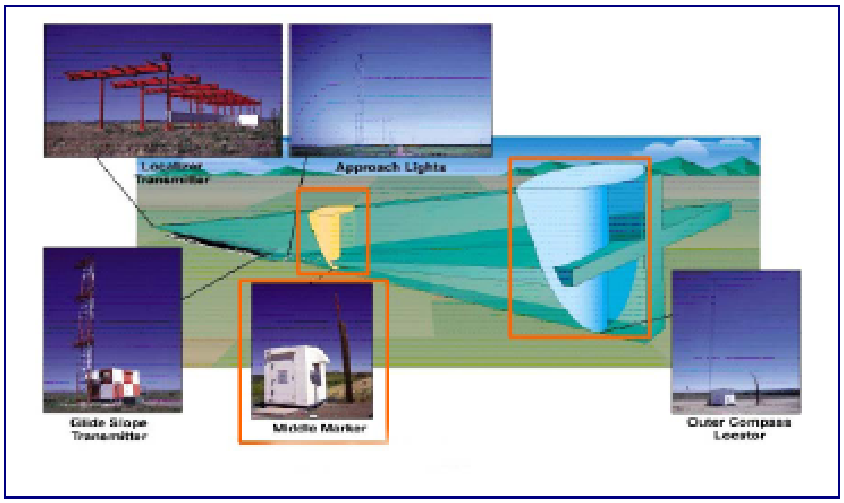
Maximum Safe Fly-Up Deviation

As seen before full-scale deviation of an ILS Glide Slope is 0.7 degree either side of the centre of the CDI. If the aircraft deviates above the Glide Slope a fly-down indication will be seen. This will continue to full-scale deflection. If the aircraft continues to deviate above the Glide Slope no further deviation is seen. This is not a dangerous situation as no ground contact is immanent, only the approach will have to be missed. If the aircraft deviates below the Glide Slope a fly-up deviation will be seen. This will continue until full-scale deviation is reached. If the aircraft continues to deviate below the Glide Slope no further indication will be seen. This becomes dangerous because there is no longer a reference as to how far the aircraft is below the Glide Slope and ground contact may now be a factor. When half full-scale fly-up deviation is reached the aircraft must initiate an immediate climb.



Marker Beacons

Marker Beacons are radio transmitters located along the centre line of the runway to indicate range to the runway threshold to the pilot. Marker Beacons are also used to manually check the crossing height of the ILS Glide Slope, indicated on the approach plate. Marker Beacons consist of three fan marker transmitters that transmit on 75 MHz carrier frequency and have different modulating tones to identify them to the pilot. The aircraft equipment consists of three lights on the instrument panel that will flash and produce an audio tone when the corresponding marker beacon transmitter is flow over.



Outer Marker

- Indicated by a blue light on the instrument panel.
- The Outer Marker transmitter is situated approximately 4 nautical miles from the runway threshold.
- The audio tone codes 2 dashes per second on a modulation of 400 Hz.

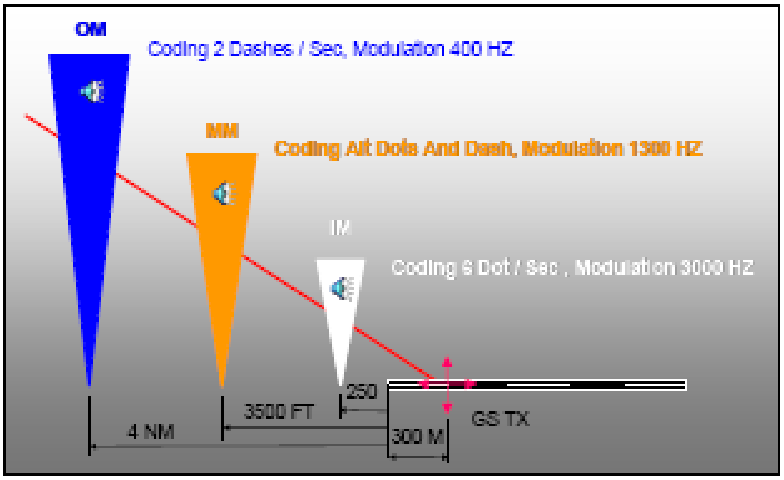
Middle Marker

- Indicated by an amber light on the instrument panel.
- The Middle Marker is situated approximately 3500 feet from the runway threshold.
- The audio tone codes alternating dots and dashes on a modulation of 1300 Hz.

Inner Marker

- Indicated by a white light on the instrument panel.
- The Inner Marker is situated approximately 250 feet from the runway threshold.
- The audio tone codes 6 dots per second on a modulation of 3000 Hz.

Marker Beacons



ILS Facility Performance Categories (ILS Ground Station)

These limitations indicate the limitations and capabilities of the ground equipment installed at the airport.

<u>Category One CAT I</u>

- Accurate guidance to 200 feet above the ILS reference datum.

<u>Category Two CAT II</u>

- Accurate guidance to 50 feet above the ILS reference datum.

<u>Category Three CAT III</u>

- Accurate guidance to the surface of the runway and along the runway centre line.

ILS Operational Approach Categories (Aircraft and Crew)

<u>Category One CAT I</u>

- A decision height of 200 feet.
- RVR of 550 meters touchdown zone. Or a visibility of 800 meters.

<u>Category Two CAT II</u>

- A decision height of 100 feet.
- RVR of 350 meters touchdown zone, 150 meters RVR mid zone.

<u>Category Three CAT III</u>

- No decision height.
- RVR of 200 meters touchdown zone and 150 meters RVR mid zone.

ILS Monitoring

An ILS is a precision approach facility and must be continually monitored for accuracy and faults. If there is a fault detected with the ILS then the three-letter identification code will be removed and the pilot must not use the facility. The following faults are monitored:

- A displacement of more than 35 feet of the Localiser from the centre line of the runway.
- A displacement of more than 0.075 times the Glide Slope angle.
- A decrease of more than 50 % of the transmitter power output.

Calculations

There are a few calculations for ILS and some have been included in the following examples. The One-in-Sixty Rule or trigonometry can be used to solve these calculations. Note that when working with trigonometry one must convert the speed from knots to feet per minute.

Rate of Descent Calculation

An ILS Glide Slope is 2.7 degrees, the IAS is 117 Kts, the TAS is 130 Kts and the ground speed is 120 Kts. What is the rate of descent to remain on the Glide Slope?

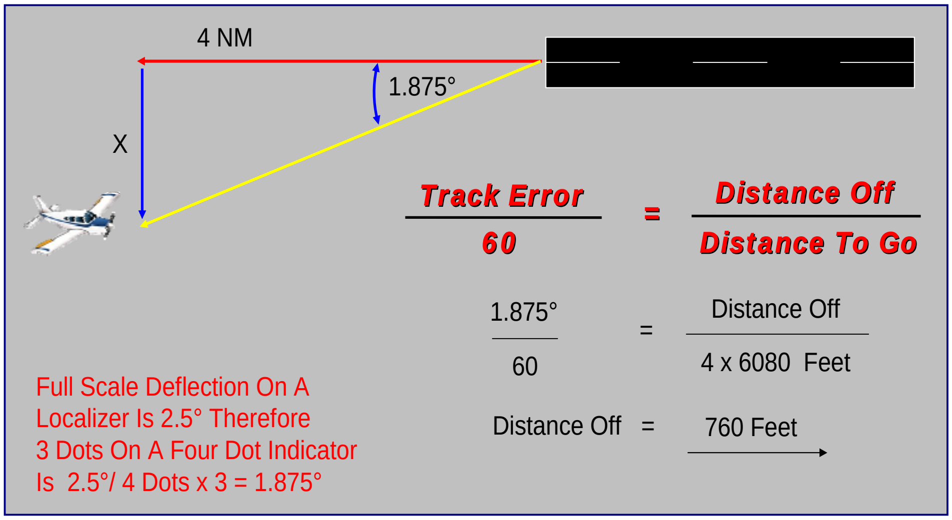
$$\text{Rate Of Descent} = \frac{\text{Glide Slope Angle} \times \text{Ground Speed} \times 100}{60}$$

$$\text{Rate Of Descent} = \frac{2.7\ \text{Degrees} \times 120\ \text{Knots} \times 100}{60}$$

$$\text{Rate Of Descent} = 540\ \text{Feet / Min}$$

General ILS question No 1

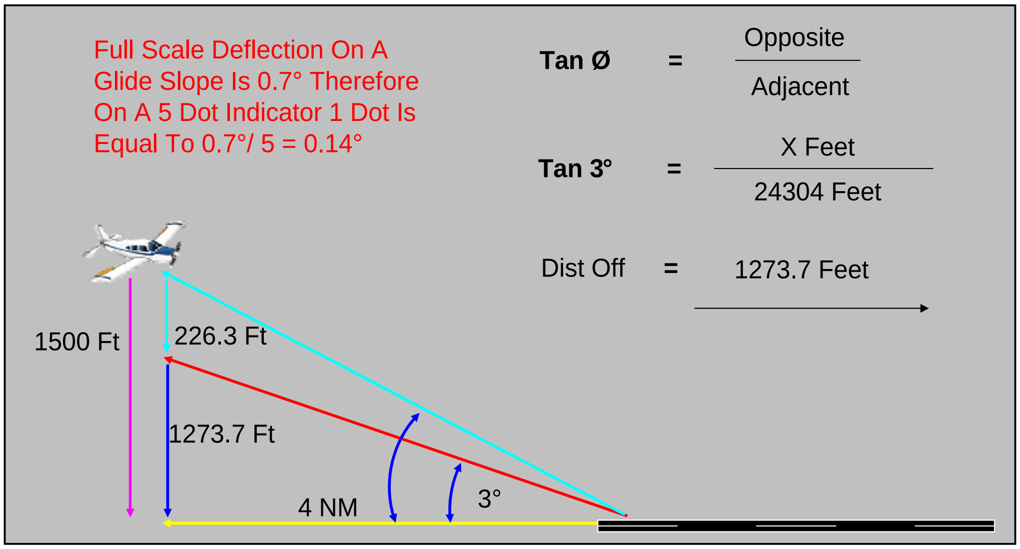
An aircraft passes the outer marker, which is four nautical miles from the threshold of a runway. The CDI shows three dots fly left on a four-dot indicator. What is the distance of the aircraft from the Localiser centre line?



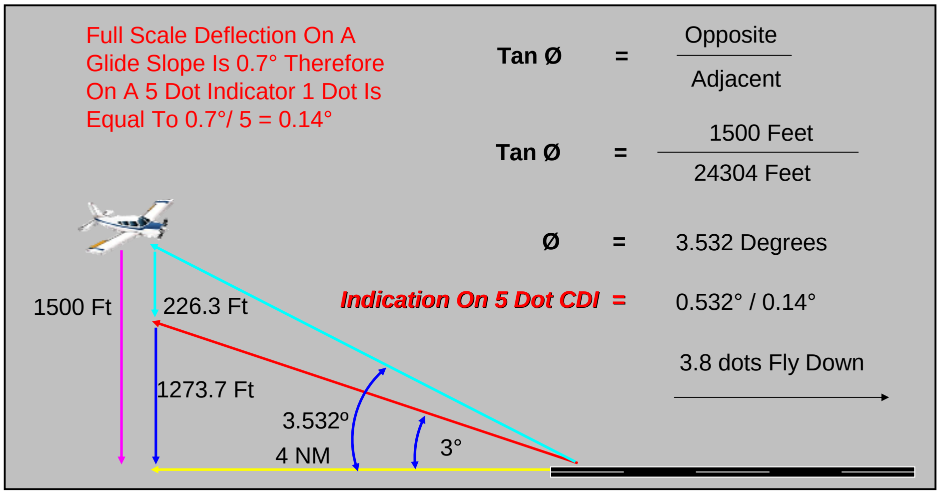
General ILS question No 2

An ILS has a 3-degree Glide Slope. The Outer Marker is four nautical miles from the runway threshold. If an aircraft passes the Outer Marker at 1500 feet above the airfield elevation, what would the Glide Slope indication on a five dot CDI be?

This is a two-part question. First work out what the aircraft height should be over the Outer Marker.



The second part of the question is to work out the difference between what the height of the aircraft should be and what height the aircraft actually is at. The difference is the indication on the CDI Glide Slope deviation bar.



WORKSHEET 4

ILS

1. The type of emission by ILS is:

   (a) A1A;
   (b) A2A;
   (c) A3E.

2. ICAO recommends that an ILS localiser should be calibrated for accuracy up to a distance of:

   (a) 18nm;
   (b) 25nm;
   (c) 35nm.

3. An aeroplane is established on an ILS localiser approaching the outer marker inbound. The ILS CDI shows a 2 dot fly up command. To intercept the glide slope the pilot should:

   (a) Climb;
   (b) Descend;
   (c) Maintain level flight.

4. Assuming that an ILS has a backbeam, an aircraft overshooting after a missed approach and has passed the localiser transmitter and is to the left on the extended line of the runway would have an ILS CDI indication of:

   (a) Fly left;
   (b) On centre line;
   (c) Fly right.

5. During the ILS approach, after passing the outer marker, a glide slope warning flag appears. The CDI needle shows on the glide slope and all indications appear normal. The appropriate action would be:

   (a) Initiate the missed approach procedure;
   (b) Continue the approach to the decision height;
   (c) Continue the approach but apply a higher minima.

6. The approximate height of an aeroplane maintaining a 2.7° glide slope during an ILS approach when over the outer marker, 4nm from the runway threshold is:

   (a) 930 feet;
   (b) 1120 feet;
   (c) 1240 feet.

7. Transmission of the ILS DENT occurs on the:

    (a) Localiser transmission;
    (b) Glide slope transmission;
    (c) Both localiser and glide slope transmission.

8. During an ILS approach to runway 03 (QDM 033), if the OBS is set to 030 and the aircraft is on the centre line the ILS CDI will indicate:

    (a) Fly left;
    (b) On localiser centre line;
    (c) Fly right.

9. An ILS glide slope is intercepted from below so as to:

    (a) Reduce the initial approach speed;
    (b) Avoid departing traffic;
    (c) Avoid false glide paths.

10. The ICAO standard height of the ILS reference point is:

    (a) 10 metres;
    (b) 15 metres;
    (c) 20 metres.

11. Full scale deflection of the ILS CDI localiser needle occurs when the aircraft is more than:

    (a) 2.5° from the centre line;
    (b) 5° from the centre line;
    (c) 10° from the centre line.

12. Full scale deflection of the ILS CDI glide slope needle occurs when the aircraft is above or below the glide path by more than:

    (a) 0.35°;
    (b) 0.7°;
    (c) 1.25°.

13. The ILS inner, middle and outer marker frequencies are:

    (a) Found in various flight guides;
    (b) Found on ILS approach plates;
    (c) 75 MHz.

14. The maximum safe deviation from the ILS glide path during an approach using a 5 dot CDI is:

    (a) 2 dots fly up;
    (b) 2½ dots fly up;
    (c) 3 dots fly up.

15. ILS marker indications are:

    (a) 3 dots fly up;
    (b) Amber light coding alternate dots and dashes;
    (c) White light coding six dots per second;
    (d) Blue light coding two dashes per second.

16. If the 150 Hz tone predominates in the ILS localiser receiver the CDI indication will be:

    (a) Fly left;
    (b) On centre line;
    (c) Fly right.

17. The rate of descent required to stay on the ILS glide path:

    (a) Must be increased if the groundspeed decreases;
    (b) Remains constant for a given IAS;
    (c) Decreases if the groundspeed decreases.

18. When making an ILS approach, the localise needle will always be deflected in the colour area in which the aircraft is flying, regardless of the position or heading of the aircraft:

    (a) The above statement is true;
    (b) If the needle indicates that the aircraft is in the BLUE sector before reaching the localiser transmitter it will give an opposite indication when the station is passed;
    (c) The above statement is false;
    (d) The YELLOW sector is always on the right when inbound to a runway.

19. Given: ILS GP 2.7 degrees, IAS 117, TAS 130, G/S 120. The rate of descent required to maintain the glide path is:

    (a) 350 ft/min;
    (b) 450 ft/min;
    (c) 550 ft/min.

20. An aircraft passes the outer marker, which is 4nm from the threshold of a runway. The CDI shows a 3 DOT fly left indication on a 4 DOT scale. The distance of the aircraft from the localiser centre line is:

    (a) 690 feet;
    (b) 780 feet;
    (c) 870 feet.

21. An ILS has a 3° glide slope. The outer marker is 4nm from the runway threshold. If an aircraft passes the outer marker at 1500 feet above airfield elevation, the glide slope indication that would be shown on a 5 DOT indicator is:

    (a) On glide path;
    (b) 2 dot fly down;
    (c) 4 dot fly down.

22. The approximate height of an aircraft above airfield elevation when on a 3° glide path and 3.8nm from the ILS reference point is:

    (a) 1200 feet;
    (b) 1500 feet;
    (c) 1800 feet.

23. The height above the ILS reference point that a CAT 1 ILS ceases to give accurate guidance is:

    (a) 100 feet;
    (b) 150 feet;
    (c) 200 feet.

24. An ILS Glide Path can be between:

    (a) 2 to 4 degrees;
    (b) 2.3 to 3.7 degrees;
    (c) Above 6 degrees.

25. ILS localiser transmissions are protected from interference up to:

    (a) 10nm;
    (b) 18nm;
    (c) 25nm.

26. A Cat 1 ILS has a glide path angle of 3.3°.
    What will its coverage be?

    (a) 1.65° to 5.77°;
    (b) 1.49° to 5.77°;
    (c) 1.65° to 5.94°.

27. You are about to begin an ILS approach for RWY 35, and have selected the ILS frequency 109.45 on the receiver. When monitoring the audio the indent signal "DFV" is heard. The localiser needle gives you the expected command indication, but the glide slope warning flag remains on. The most likely reason for this is that:

    (a) The glide slope transmitter is not operational;
    (b) The aircraft is out of the glide slope area of coverage;
    (c) The selected frequency is incorrect.

Chapter 8

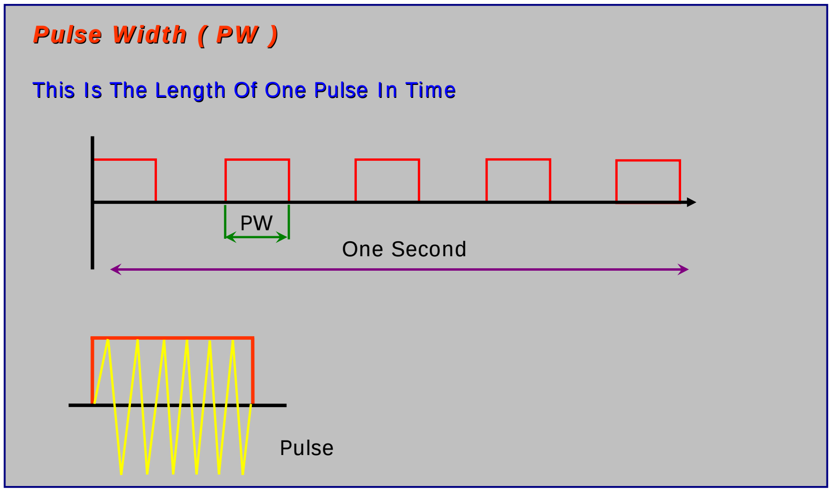
BASIC RADAR

RADAR is short for **Ra**dio **D**etection **A**nd **R**anging. Radar is the transmission of normal radio energy in short bursts or pulses. The frequencies used in Radar are in the VHF and higher frequency bands. There are basically two types of radar in this syllabus; they are Primary Radar and Secondary Radar. Primary Radar is used for ranging and direction while Secondary Radar is used for identification.

Pulse Terminology

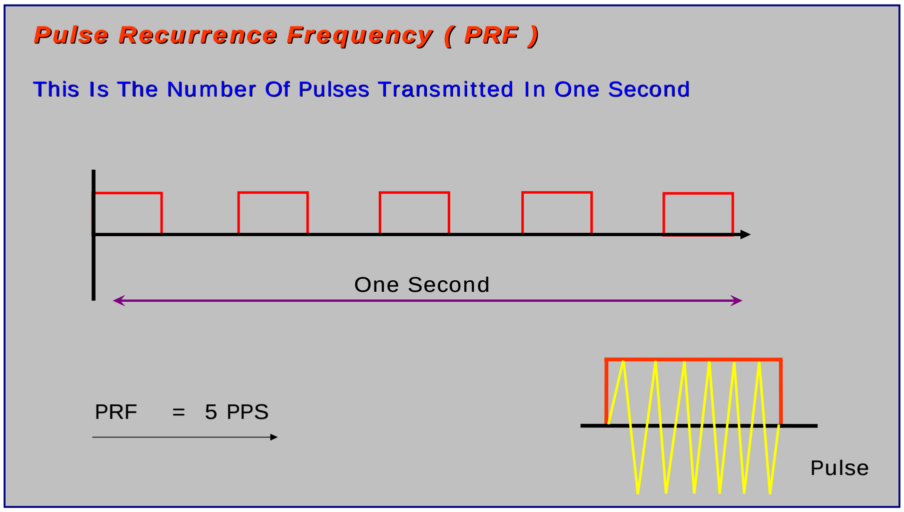
Pulse Width

Pulse Width may be defined as the length of a pulse in time and is measured in seconds. An example of an average pulse width is 2µ seconds.



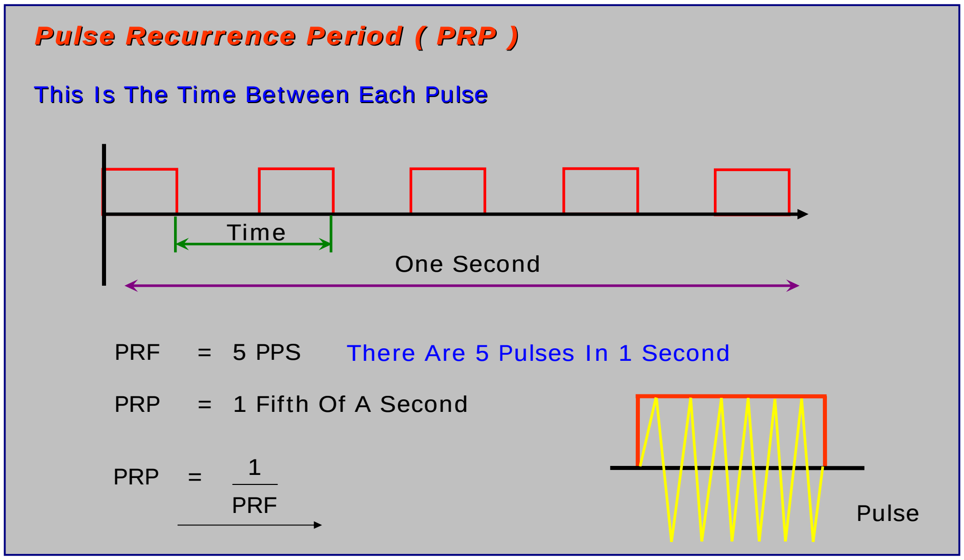
Pulse Recurrence Frequency (PRF)

Pulse Recurrence Frequency may be defined as the number of pulses in one second. An example of an average PRF is 400 pulses in one second.



Pulse Recurrence Period (PRP)

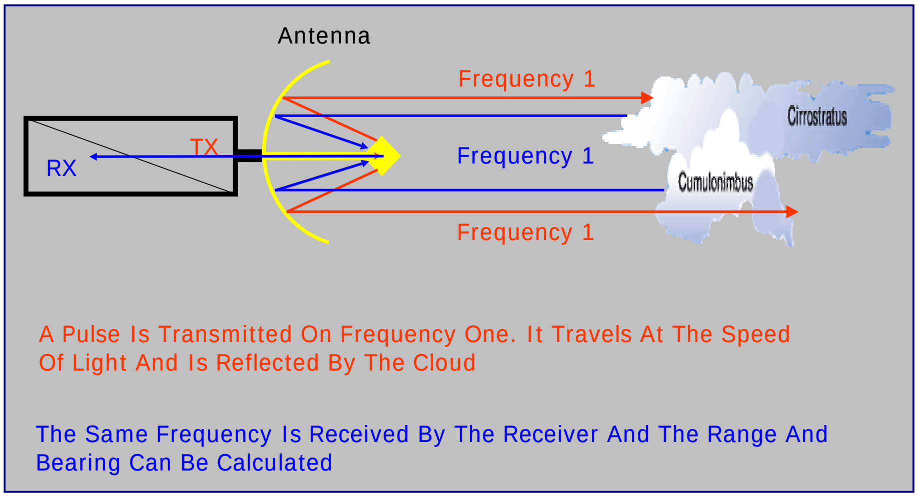
Pulse Recurrence Period may be defined as the time interval between two pulses and is measured in seconds.



Primary Radar

Primary Radar is used mainly in search radar to obtain range and bearing of an object. Depending on the type of radar used, radio energy is transmitted from the directional rotating radar antenna, much like a lighthouse beam. The radio energy is reflected back to the antenna, the direction from which the radio energy is received is the bearing or the direction of the object. The time it took the radio energy to return to the antenna is used to calculate the range of the object. This type of radar is also called an Echo Radar. Primary Radar is considered to have the following basic components:

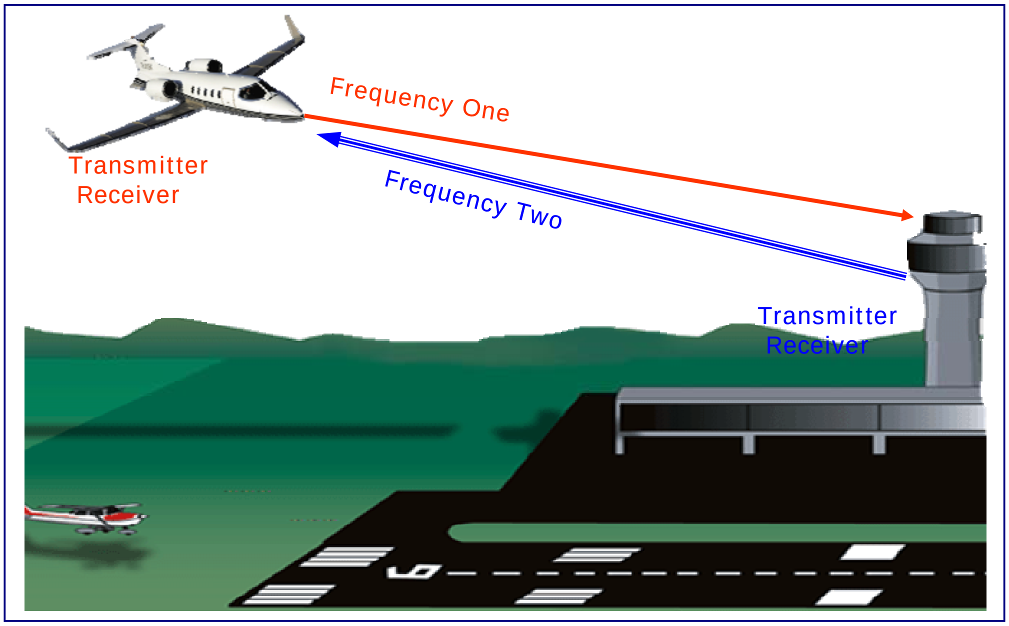
- One transmitter.
- One receiver.
- One antenna.
- One frequency.



Secondary Radar

Secondary Radar is much like two-way radio communication except that the information is pulsed and not a continuous wave transmission. Secondary Radar will use both airborne equipment and ground station equipment to transfer information. Secondary Radar is considered to consist of the following components:

- Two transmitters; one in the aircraft and one on the ground.
- Two receivers; one in the aircraft and one on the ground.
- Two antennae; one in the aircraft and one on the ground.
- Two frequencies; one transmitted by the aircraft and the other by the ground.



Primary Radar Ranging

Primary ranging is achieved by measuring the time interval from when a pulse is transmitted to when the same pulse is received and then multiplied by the speed of the radio wave. The time interval must be divided by two, as the radio wave must travel outbound and return making the time interval too long.

The range that the Radar can achieve is determined by the power output of the radio, to double the range of the Radar, the power has to be increased sixteen times. The range of the Radar also depends on the following factors:

- Pulse Recurrence Frequency; PRF determines the maximum range of the Radar.
- Pulse Recurrence Period is the time the pulse has to travel before the next pulse is transmitted.
- Pulse Width PW determines the minimum range of the Radar.

It must also be noted that a Primary Radar cannot transmit and receive at the same time and that the transmitter controls the system. If a pulse is not back at the receiver before the next pulse is transmitted it will be ignored and no information will be displayed. As the timing of the pulses is a function of PRF, the PRF controls the maximum range. The higher the PRF of the radar the shorter the time interval between the pulses and thus the less the maximum range. Because the radar cannot receive and transmit at the same time, if a target is closer than the pulse width PW is wide, information sent back to the receiver will not be received during the transmission phase of the radar. Thus, PW controls the minimum range of the radar.

PRF - Maximum Range
PRP - Time For The Pulse To Travel
PW - Minimum Range

$$\text{Range (M)} = \frac{\text{Speed} \times \text{Time}}{2}$$

Radar Range Calculation No 1

A radar system has the following specifications, a PRF of 400 pulses per second and a pulse width of 2µ seconds. Calculate the maximum and minimum range of the radar.

Maximum Range

$$\text{Range (M)} = \frac{\text{Speed} \times \text{Time}}{2}$$

$$\text{Time} = \text{PRP}$$

$$\text{Time} = \frac{1}{400 \text{ PPS}}$$

$$\text{Time} = 0.0025 \text{ Seconds}$$

$$\text{Range (M)} = \frac{\text{Speed} \times \text{Time}}{2}$$

$$\text{Range (M)} = \frac{3 \times 10^{8} \text{ Meters / second} \times 0.0025 \text{ Seconds}}{2}$$

$$\text{Range (M)} = \frac{750000 \text{ Meters}}{2}$$

$$\text{Range (M)} = 375000 \text{ Meters} \quad \text{Or} \quad 375 \text{ KM}$$

Minimum Range

$$\text{Range (M)} = \frac{\text{Speed} \times \text{Time}}{2}$$

$$\text{Range (M)} = \frac{3 \times 10^{8} \text{ Meters / second} \times 2 \times 10^{-6} \text{ Seconds}}{2}$$

$$\text{Range (M)} = \frac{600 \text{ Meters}}{2}$$

$$\text{Range (M)} = 300 \text{ Meters} \quad \text{Or} \quad 0.3 \text{ KM}$$

Radar Range Calculation No 2

Calculate the complete number of cycles in the following radar pulse. The frequency of the radar is 9.375GHz. The pulse width is 3µ seconds.

$$\lambda = \frac{C}{F}$$

$$\lambda = \frac{3 \times 10^{8} \text{ Meters / second}}{9.375 \times 10^{9} \text{ HZ}}$$

$$\lambda = 0.032 \text{ Meters}$$

Range (M) = Speed X Time

Range (M) = 3×10^{8} Meters / second X 3×10^{-6} Seconds

Range (M) = 900 Meters

Each Cycle Is 0.032 Meters Therefore The Number Of Complete Cycles Is

$$\text{Cycles} = \frac{900 \text{ Meters}}{0.032 \text{ Meters}}$$

Cycles = 28125

Chapter 9

Cathode Ray Tube (CRT)

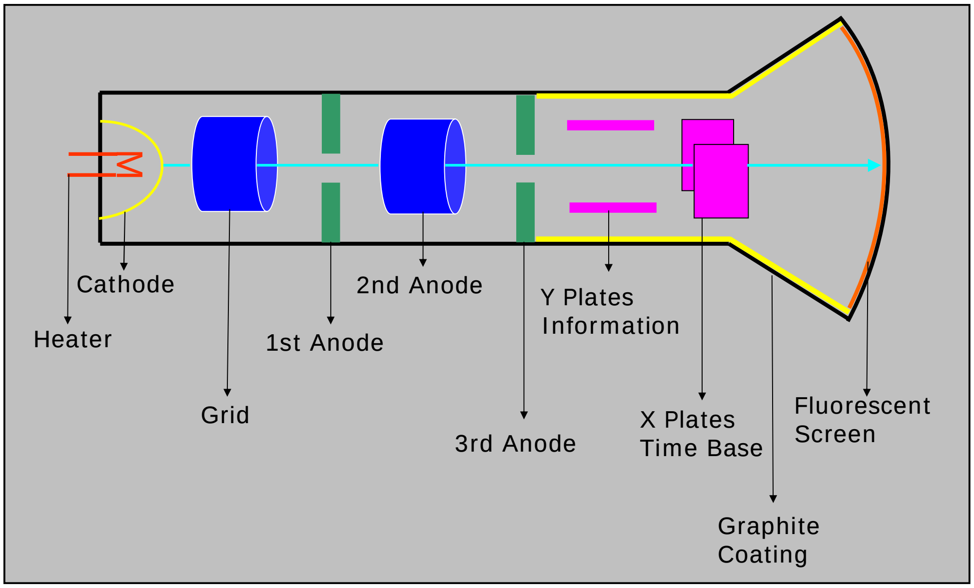
A Cathode Ray Tube is a device that uses high-speed electrons to produce an image on a glass screen much like that of a television screen. A Cathode Ray Tube consists of five basic components:

- A glass tube that has been evacuated.
- An electron gun or an electron-producing component.
- A focusing component.
- An acceleration component.
- And a deflection component.

A Cathode Ray Tube will produce an Electron Beam that will strike the front of the tube or screen. The screen is coated with a fluorescent substance that converts kinetic energy from the electrons into light energy. By controlling the beam in both the vertical and horizontal a picture can be formed. The CRT that will be discussed will be the Electrostatic type. This type of CRT utilises electrostatic focusing and deflection.

Components of the Cathode Ray Tube

The following components of the CRT will be discussed:



Heater

The Heater is a tungsten filament that when supplied with electrical power will glow hot like that of a light bulb. The purpose of the Heater is to heat the Cathode.

Cathode

The Cathode consists of a small metal cylinder coated with Barium Oxide. When the Cathode is heated it will give off a cloud of electrons, which are negatively charged particles.

Grid

The Grid is placed around the Heater and Cathode assembly and is charged with a negative potential or voltage. The negative voltage of the Grid repels the negatively charged electrons and concentrates them into a beam. The Grid is used to control the brilliance of the CRT.

First Anode

The First Anode is positively charged and thus attracts the electrons. This is the first electron acceleration stage.

Second Anode

The Second Anode is negatively charged with respect to the electrons and repels the electrons away from the walls of the glass tube. This Anode is used to focus the Electron Beam by changing the potential on the Second Anode.

Third Anode

The Third Anode has a very high positive potential and is used for the final acceleration of the electrons.

Y Deflection Plates

These deflection plates are used to control the Electron Beam in the vertical plane. The Y deflection plates lie in the horizontal plane. By applying a voltage to the plates i.e. a positive voltage to the top plate and a negative voltage to the bottom plate the beam will be deflected upwards. If we reverse the polarity on the plates the Electron Beam will be deflected downwards. The required information to be displayed is applied to the Y deflection plates.

X Deflection Plates

These deflection plates are used to control the Electron Beam in the horizontal plane. The X deflection plates lie in the vertical plane. By applying a voltage to the plates i.e. a positive voltage to the left plate and a negative voltage to the right plate the Electron Beam will be deflected to the left. If the polarity of the voltage is reversed the Electron Beam will be deflected to the right. A time base voltage is applied to the X deflection plate to move the Electron Beam across the screen.

Graphite Coating

A Graphite Coating is applied to the inside of the front of the tube to trap secondary electrons that are out of the Electron Beam. These electrons are sent to the Third Anode to reintroduce them into the Electron Beam to prevent a cloud of electrons forming behind the screen. This electron cloud may affect the Electron Beam as it travels to the screen.

Fluorescent Screen

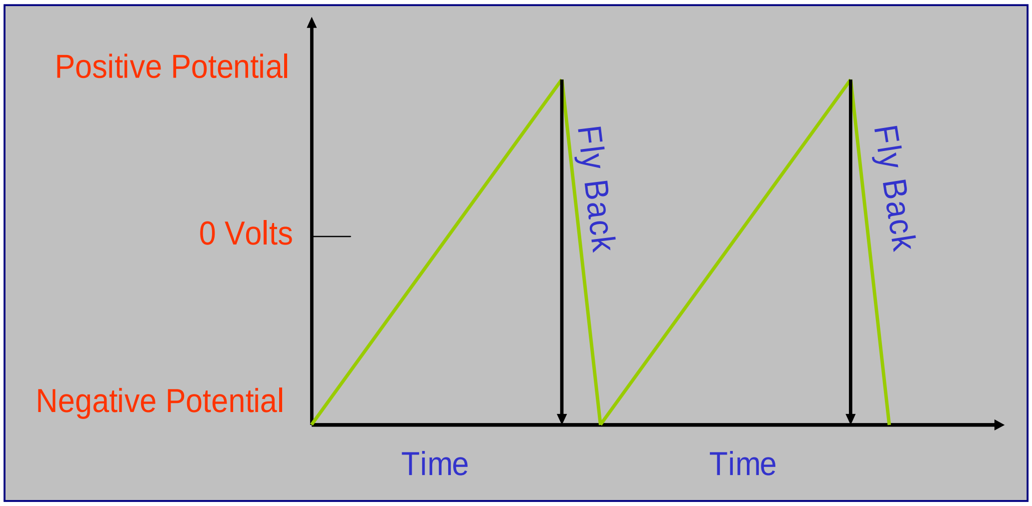
The front of the Cathode Ray Tube is coated with a Fluorescent Coating that will glow when struck by electrons. The image may remain for a few milliseconds to a few seconds and this is known as Persistence.

Gain Control

The Gain Control is used to adjust the sensitivity of the receiver. By reducing the gain of the receiver, clutter or noise is reduced. This clutter or noise is called Grass.

CRT Time Base Voltage

The Time Base is applied to the X plates and is used to control the Electron Beam in the horizontal direction across the screen. By changing the polarity of the voltage from a negative potential, which repels the Electron Beam to the far left of the screen to a positive, potentially moves the Electron Beam to the far right of the screen. The Time Base Voltage is then returned to the original negative voltage very quickly causing the Electron Beam to move back to the far left of the screen - this is called Fly Back. During this time the Electron Beam is not seen on the screen by making the Grid potential very negative.



WORKSHEET 5

Basic Radar

1. In primary radar installations, the pulse width determinates the:

   (a) Maximum range;
   (b) Minimum range;
   (c) Pulse recurrence frequency.

2. In primary radar installations, the pulse recurrence frequency determines the:

   (a) Maximum range;
   (b) Minimum range;
   (c) Pulse width.

3. The anode system of the Cathode Ray Tube:

   (a) Controls the brilliance of the display;
   (b) Controls the number of electrons reaching the screen and leads stray electrons to earth;
   (c) Accelerates the electron beam towards the screen and acts as a focus control.

4. The inner wall of the Cathode Ray Tube is coated with graphite:

   (a) To provide protection to the operator;
   (b) To attract stray electrons and leads them to an earth;
   (c) To screen the CRT from outside interference.

5. Basic radar is the transmission of pulses of radio energy. The time interval between two consecutive pulses in time is the:

   (a) Pulse Recurrence Frequency;
   (b) Pulse Recurrence Period;
   (c) Pulse Recurrence Sequence.

6. The brilliance of a CRT display is controlled by:

   (a) The second anode;
   (b) The first and third anodes;
   (c) The grid.

7. Unwanted echoes or “grass” can be reduced or removed from a horizontal time base on a CRT by:

   (a) X plates;
   (b) Y plates;
   (c) The gain control.

8. To double the range of primary radar the transmission power must be increased by a factor of:

   (a) 4;
   (b) 8;
   (c) 16.

Chapter 10

Distance Measuring Equipment (DME)

Distance Measuring Equipment or DME is a short-range navigational aid that is used to supply slant-line range in nautical miles from the ground station to the aircraft. Distance Measuring Equipment uses the principal of Secondary Radar to calculate range.

Summary for Distance Measuring Equipment

Frequency

The DME operates in the UHF radio frequency band from 962 MHz to 1213 MHz at 1 MHz channels. Frequencies are divided into a low band and a high band. The DME frequencies are frequency paired with the VOR navigation radio.

Transmission

The DME uses the principal of Secondary Radar to calculate range. The DME is a vertically polarised radio system.

Range

DME radio operates in the UHF radio frequency band, which is a line-of-sight direct wave. The range is approximately 200 nautical miles line-of-sight.

Aircraft Equipment for DME

DME Transmitter / Receiver

The DME Transmitter / Receiver in the aircraft is used to transmit aircraft interrogation pulses to the ground station. The ground station or the transponder transmits a response signal to the aircraft. The time between when the pulse is transmitted from the aircraft to when it is received by the aircraft is measured and used to calculate distance.

DME Antenna

The DME antenna is a vertical omni-directional blade antenna mounted on the underside of the aircraft. Each radio system will have its own antenna.

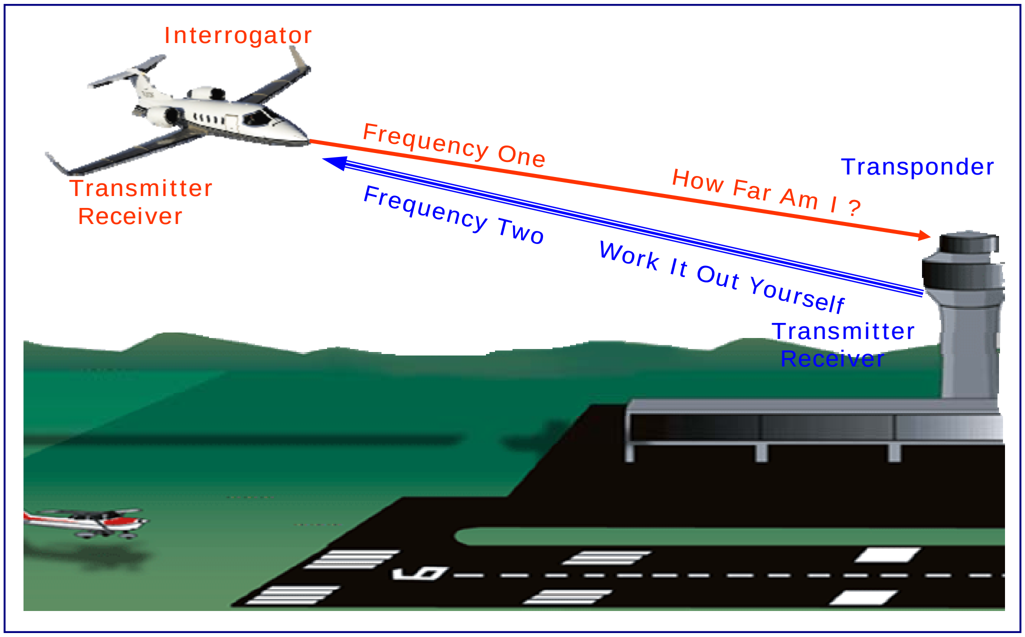
DME Indicator

The DMI indicator is used to supply the pilot with slant-line-range to a ground station in nautical miles.

Principle of Operation

The DME operates on the following principle:

- DME uses Secondary Radar to calculate range.
- An aircraft transmits an interrogation pulse on one frequency, which is received by the ground station.
- The transponder or ground station will respond to the aircraft pulse and send a reply pulse on a different frequency.
- The ground station transmits all the interrogation pulses it receives, so the aircraft receivers must differentiate which signals belong to which aircraft. This is accomplished by using random PRF, discussed later.



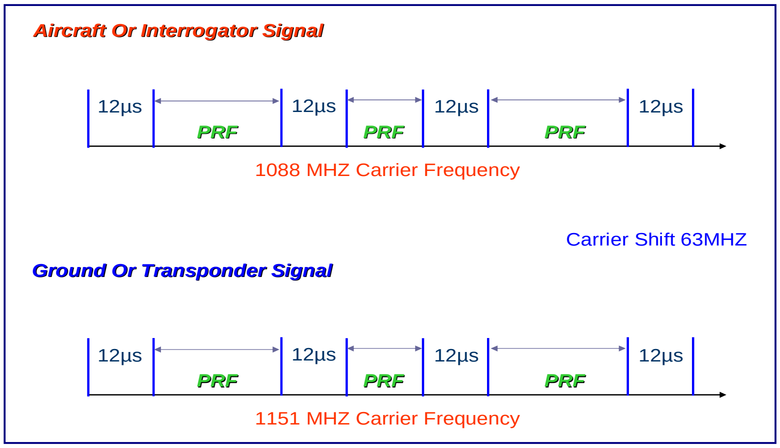
DME Signal

DME transmits in the UHF radio frequency band and transmits a set of pulse pairs that are 12µ apart. The pulse pairs are randomly spaced, called the DME random PRF. The signal is transmitted to the ground station where it is delayed for 50µ seconds. This delay is so that the ground station can amplify the signal and shift the carrier frequency by 63 MHz. This signal is transmitted back to the aircraft on the shifted carrier frequency.

To summarise the DME signal the following can be considered:

- Random PRF is to ensure that the aircraft receives only the signals meant for itself as the DME station transmits all the signals that it receives.

- Frequency shift is to ensure that an echo or a reflection is not used as information to calculate range. The frequency shift can only be accomplished by a ground station.



DME Search Mode

When a VOR / DME station is selected the DME radio in the aircraft will perform a series of Search Modes to find and calculate range as soon as possible. The lock on procedure is as follows:

During Search Mode

The transmitter transmits 150 pulses per second for 100 seconds i.e. 15000 pulse pairs. In those 100 seconds one of two conditions can occur:

- If no station is found the transmitter will drop its transmission rate to 60 pulses per second for a while then go into Automatic Standby and wait for a station to get into range.

- If a station is found within 100 seconds the DME radio in the aircraft will calculate range. Once the calculation is done the transmitter reduces its transmitting rate to between 24 to 30 pulse pairs per second.

Memory Mode

If the DME signal is lost the DME radio in the aircraft switches to Memory Mode. The Memory Mode is valid for ten seconds, in this time the DME indicator will continue to show distance and the transmitter is prevented from going into Search Mode. If the signal is not received within ten seconds the DME radio in the aircraft will return to Search Mode.

Automatic Standby

When the DME radio in the aircraft is out of range it is pointless to transmit for no reason, so the transmitter switches to Standby Mode. The problem with this mode is that the aircraft radio or the interrogator must make the transmission to the station or transponder before an answer can be received from the ground station. The ground station transmits filler pulses to switch the interrogator out of Standby Mode so that it can interrogate the ground station to calculate range. The aircraft radio will also switch out of Automatic Standby when it receives DME information meant for other aircraft, known as Squitter.

DME Identification

The Distance Measuring Equipment will identify every 37.5 seconds with a three letter Morse Identification Code.

DME Saturation

The DME can only reply to 100 aircraft at a time. If there are more then a 100 aircraft interrogating the DME station, the station will reduce its receiver gain and only respond to the nearest 100 aircraft with the strongest signal strength.

DME Accuracy and Errors

Distance Measuring Equipmet does not suffer from any errors and is accurate to about 0.5 nautical miles. When using DME range it must be noted that the distance is calculated using a line-of-sight radio wave i.e. in the UHF frequency band there is no refraction of the radio wave. The line-of-sight distance is from the aircraft to the ground station and is longer than the true ground range if the aircraft is at altitude.

DME Frequency Band

The DME frequency band is divided into two bands; the low band in which the ground station will subtract 63 MHz from the carrier frequency and a high band in which the ground station will add 63 MHz to the carrier frequency. This is done to increase the number of channels to 126 available for DME

DME Ground Station Frequencies : UHF 962 MHZ 1213 MHZ

Low Band :	Subtract 63 MHZ	
Interrogator (Aircraft)		***Transponder (Station)***
1025 MHZ To 1087 MHZ		962 MHZ To 1024 MHZ

High Band :	Add 63 MHZ	
Interrogator (Aircraft)		***Transponder (Station)***
1088 MHZ To 1150 MHZ		1151 MHZ To 1213 MHZ

VOR DME Frequency Pairings

The VOR and DME frequencies are paired to reduce flight deck workload. When a VOR frequency, which is in the VHF frequency band, is selected a DME frequency, which is in the UHF frequency band, is automatically selected or paired with the VOR.

Co-Located VOR and DME

The antennas of the two radios are less than 100 feet apart. The identification is the same for both DME and VOR. This type of VOR / DME is used for terminal approach aids.

Associated VOR DME

The antennas of the two radios are more than 100 feet apart but less than 2000 feet apart. The identification is the same for both the VOR and the DME. This type of VOR / DME is used for en-route aids.

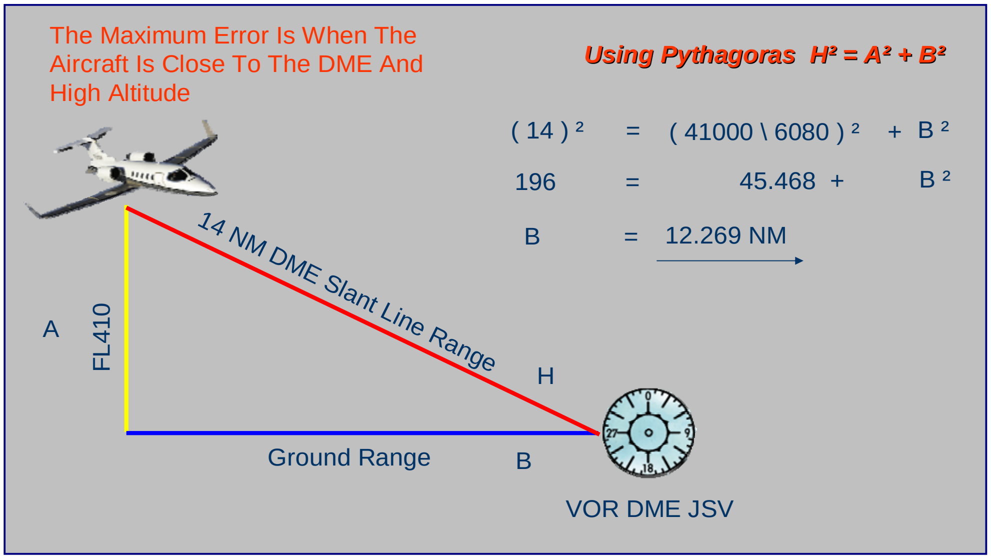
Serving the Same Location

When the antennas of the two radios are more than 2000 feet apart, the distance apart will be published in a flight guide. The identification for VOR and DME are different in that the DME will have the same first two letters as the VOR but the last letter will identify as a Z. This type of VOR / DME is used for en-route aids.

DME Calculations

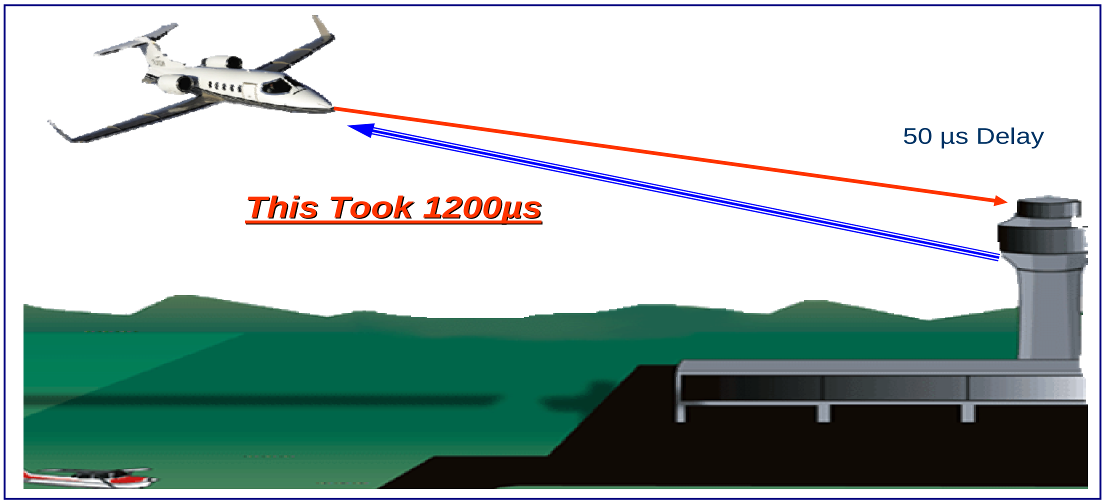
Example No 1

An aircraft at flight level 410 has a DME range of 14 nautical miles. What is the ground range from the DME station?



Example No 2

An aircraft receives a reply pulse from a DME station 1200 µs after transmission of the interrogator pulse. The DME station has a fixed delay of 50µs. What is the range of the aircraft from the DME station?



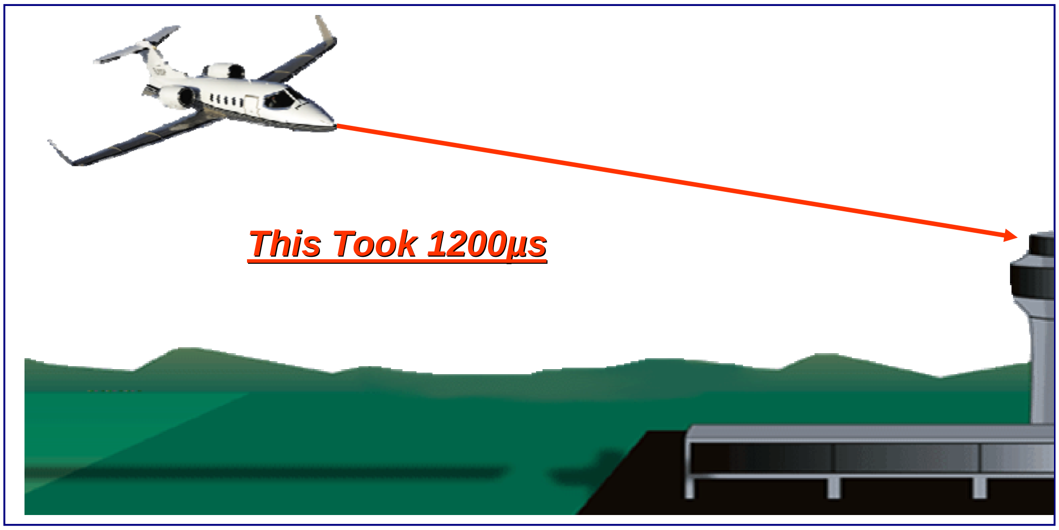
$$\text{Range (M)} = \frac{\text{Speed In Meters / Second} \times \text{Time In Seconds - } 50\mu s}{2}$$

$$\text{Range (M)} = \frac{3 \times 10^{8} \text{ Meters / Second} \times (1200 \times 10^{-6} - 50 \times 10^{-6})}{2}$$

Range (M) = 172500 Meters Or 172.5 KM Or 93 NM

Example No 3

A DME station receives an interrogation pulse 1200µs after transmission. The DME station has a fixed delay of 50µs. What is the range of the aircraft from the DME station?



Range (M) = Speed In Meters / Second x Time In Seconds

Range (M) = 3×10^{8} Meters / Second x 1200×10^{-6}

Range (M) = 360000 Meters Or 360 KM Or 190 NM

WORKSHEET 6

DME

1. The DME indications when an aircraft is overhead a VOR/DME station at 6000' is:

   (a) 0 nm;
   (b) 1 nm;
   (c) 1.3 nm.

2. The distance displayed by the DME indicator is:

   (a) Slant range in nautical miles;
   (b) Slant range in statute miles;
   (c) Correct ground range.

3. The greatest error between ground distance to the DME station and the indicated distance is:

   (a) High altitudes at maximum range;
   (b) High altitudes close to the DME station;
   (c) Low altitudes at maximum range;
   (d) Low altitudes close to the DME station.

4. The DME frequency band is:

   (a) VLF;
   (b) VHF;
   (c) UHF.

5. A VOR frequency is selected and VOR and DME indications are received on the appropriate indicators. The VOR ident is CPL and the DME CPZ. This indicates that VOR and DME transmitters are:

   (a) Co-located, and the bearing and range can be plotted from the VOR position;
   (b) Serving the same location and may be plotted after checking the two positions;
   (c) At two independent positions and are not related.

6. A DME transponder becomes saturated if interrogated by an excessive number of aircraft. It will reply to the nearest:

   (a) 80 aircraft;
   (b) 100 aircraft;
   (c) 120 aircraft.

7. An aircraft DME receiver rejects pulses meant for other aircraft because:

   (a) The transmission and reply frequencies are 63 MHz apart;
   (b) The random PRF is unique to each aircraft;
   (c) The pulse is transmitted in pairs.

8. An aircraft receives a reply pulse from a DME 1200 μs after transmission of the interrogation pulse. The DME has a fixed delay of 50 μs. The range of the aircraft from the DME station is:

   (a) 47 nm;
   (b) 72 nm;
   (c) 93 nm.

9. A DME with a fixed delay of 50 μs receives an interrogation pulse from an aircraft 285 μs after transmission. The slant range of the aircraft from the DME station is:

   (a) 29 nm;
   (b) 46 nm;
   (c) 63 nm.

10. The DME automatic standby will activate the DME interrogator when:

   (a) Random filler pulses from the transponder are received;
   (b) A VOR frequency that has a frequency paired DME is selected;
   (c) The DME ident signal is received.

11. If an ident signal is received once in 30 seconds ~ on a frequency paired VOR/DME, then:

   (a) The VOR only is operational;
   (b) The DME only is operational;
   (c) Both facilities are operational.

12. An aircraft's DME receiver will accept replies to its own interrogations from a DME transponder and ignore replies to interrogations from other aircraft because the:

   (a) Interrogation and reply frequencies are 63 MHz apart;
   (b) Random PRF which is unique to each transmitter;
   (c) Pulses are transmitted in pairs.

13. An aircraft will not accept replies from its own transmissions that are reflected from the ground because the:

   (a) Interrogation and reply frequencies are 63 MHz apart;
   (b) Random PRF which is unique to each transmitter;
   (c) Pulses are transmitted in pairs.

14. A VOR frequency is selected and VOR and DME indications are received on the appropriate indicators. The VOR ident is GDV and the DME MFT. This indicates that VOR and DME transmitters are:

    (a) Co-located, and the bearing and range can be plotted from the VOR position;
    (b) Serving the same location and may be plotted after checking the two positions;
    (c) At two independent positions and are not related.

15. An aircraft DME interrogator transmits pair of pulses for limited periods at switch on. The transmission pattern is:

    (a) 150 pps for 100 seconds, thereafter 60 pps until lock on, then 27 pps;
    (b) 15000 pps for 100 seconds, thereafter 60 pps until lock on, then 27 pps;
    (c) 270 pps for 100 seconds, thereafter 150 pps until lock on, then 25-30 pps.

16. An aircraft receives a reply from a DME (fixed delay 50 μs) 995 μs after transmission of the interrogation pulse. The slant range of the aircraft is:

    (a) 76.54nm;
    (b) 82.59nm;
    (c) 88.34nm.

17. An aircraft receives a reply from a DME 1.5 milli-seconds after transmission of the interrogation pulse. If the DME has a fixed delay of 50 μs the range of the aircraft is:

    (a) 112.85nm;
    (b) 117.45nm;
    (c) 121.83nm.

18. An X channel DME transponder will not reply to a Y channel interrogation, because:

    (a) The interrogation and reply frequencies are 126 MHz apart;
    (b) The Y channel accepts three pulses interrogations only;
    (c) The spacing between the X and Y interrogation pulses is different.

19. An aircraft at FL 410 has a DME range of 14 nm. The ground range from the DME is:

    (a) 11.86nm;
    (b) 12.27nm;
    (c) 12.85nm.

Chapter 11

Secondary Surveillance Radar (SSR)

Transponder or Secondary Surveillance Radar is used in conjunction with Primary Radar to provide identification of an aircraft to Air Traffic Control. Primary Radar will give the Air Traffic Controller the range and bearing of the aircraft while the Secondary Surveillance Radar will identify the aircraft. The primary target is displayed on a Plan Position Indicator or PPI, also known as the radar screen, as a dot or a blip. The target is then identified by a label produced by the SSR and ground computer equipment. The radar antenna rotates between six to twenty five times a minute and is synchronised with the PPI.

Summary for the Secondary Surveillance Radar

Frequency of Operation

The Secondary Surveillance Radar operates in the UHF radio frequency band. The frequencies used are 1030 MHz and 1090 MHz.

Transmission

The Secondary Surveillance Radar uses Secondary Radar as its principal of operation. The radio wave is vertically polarised.

Emission Of SSR

The radio wave emission from a Secondary Surveillance Radar is classifies as M1D.

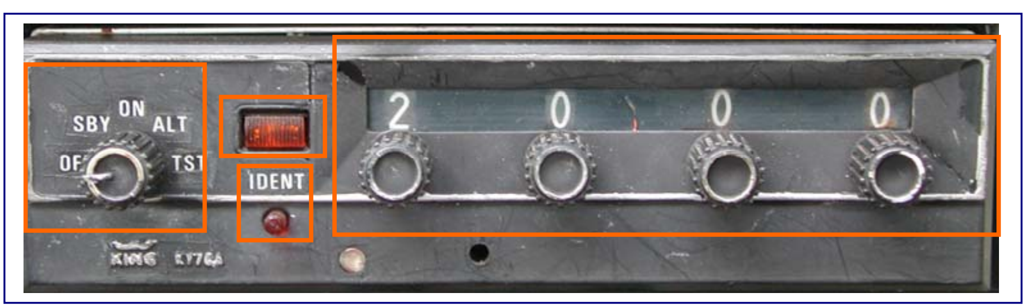
Range of SSR

The Secondary Surveillance Radar operates in the UHF radio frequency band and thus has a line-of-sight radio wave. It has a range of approximately 200 nautical miles.

Aircraft Equipment

Transponder Transmitter / Receiver

The Transponder is used by the pilot to select the required code requested by Air Traffic Control. The Transponder receives interrogations form the ground and will respond to those interrogations with the squawk code requested by ATC and on most Transponders transmit the aircraft flight level.



Squawk Code Switches

These selectors are used to select the required squawk code requested by ATC. Each of the four selectors can select between 0000 and 7777, this is due to the Binary principal of operation of the squawk code system.

Function Switch

This rotary switch is used by the pilot to control the Transponder and has the following functions:

- **OFF**: In this position the radio is not powered.
- **STBY**: In this position the Transponder is not transmitting but the system is powered. The Transponder should be placed in this position during pre-flight to allow the radio to warm up before use.
- **ON**: In this position the Transponder is powered and transmitting the selected squawk code but is not transmitting the aircraft flight level.
- **ALT**: In this position the Transponder is powered and transmitting the selected squawk code as well as transmitting the aircraft flight level. The flight level information is not affected by the altimeter barometric setting.
- **TST**: In this position the pilot can test the Transponder. If the test is successful the light will come on.

Ident Button

This function is only used on request by ATC. Do not use this function when changing squawk codes. When this button is pressed the Transponder transmits a Special Identification Pulse or SIP pulse, which causes your target to "MUSHROOM", or get brighter so that ATC can easily identify your target on the radar screen.

Reply Light

This orange / green light illuminates when the Transponder replies to a ground station. The pilot can easily see if the transponder is functioning by observing the light.

Transponder Antenna

This is a small blade antenna much like the DME antenna. The antenna is vertically polarised and is mounted on the underside of the aircraft. There is an antenna for each Transponder.

Secondary Surveillance Radar Ground Equipment

Plan Position Indicator PPI

This is the radar screen used by the Air Traffic Controller to see and control the aircraft.

The PPI is synchronised with the antenna and rotated between 6 and 25 times per minute. From this PPI the ATC can obtain range and bearing of the aircraft.

Radar Antenna

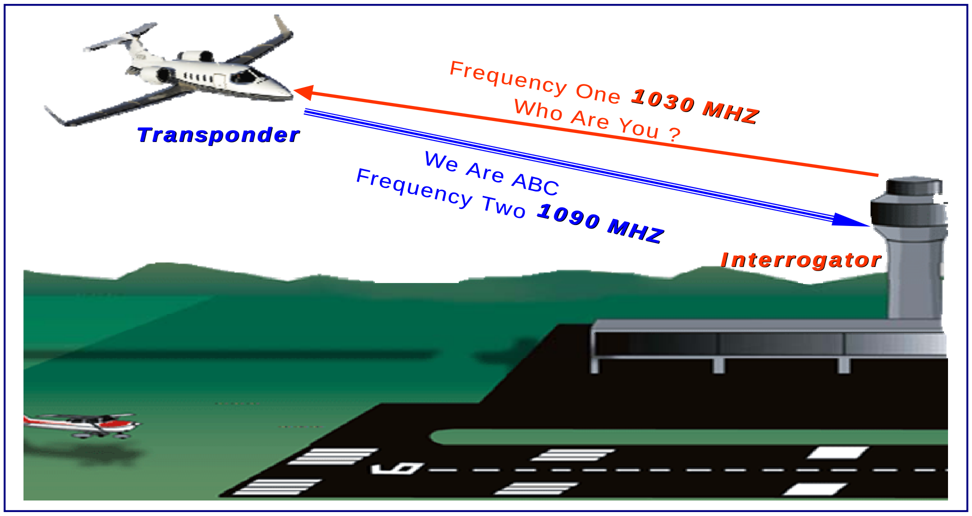
The radar antenna is used to transmit and receive radio frequencies in the Super High Frequency band.

Principal of Secondary Surveillance Radar Operation

The Secondary Surveillance Radar operates in the following way:

- The SSR uses Secondary Radar to identify the aircraft and Primary Radar to obtain the target.
- A ground station transmits an interrogation pulse, which is received by the aircraft on a carrier frequency of 1030 MHz.
- The Transponder or aircraft equipment will respond to the ground station and send a reply pulse on a carrier frequency of 1090 MHz.
- The reply pulse will identify the aircraft by means of a squawk code requested by ATC.
- ATC uses Secondary Radar and Primary Radar to obtain range bearing and identification of the aircraft.

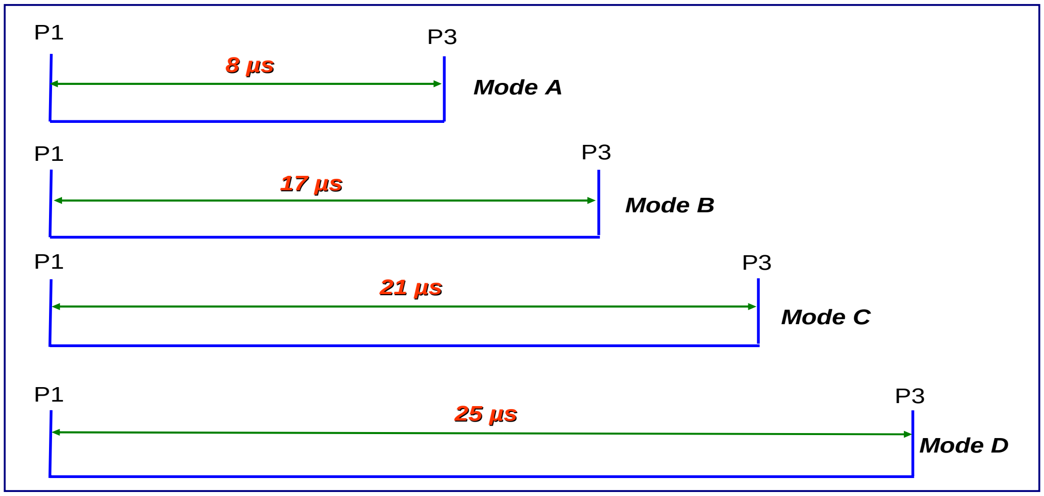
Principal of Secondary Surveillance Radar Operation



Ground Station Interrogation Modes

The ground station can transmit two framing pulses of varying width depending on the type and sophistication of the station. There are four modes and they are as follows:

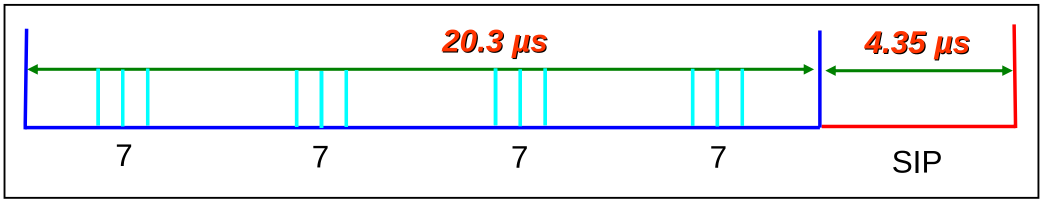
- **Mode A**: The framing pulses are 8µs wide and are used for identification request.
- **Mode B**: The framing pulses are 17µs wide and are used for identification request.
- **Mode C**: The framing pulses are 21 µs wide and are used for altitude information.
- **Mode D**: The framing pulses are 25 µs wide and are used for experimental purposes.



Aircraft Transponder Mode

The aircraft reply framing pulses are of constant width and are the following:

- The pulses are a constant width and are 20.3 µs wide, with the squawk code pulses in between the framing pulses.
- The selected squawk code is a combination of twelve Binary bits. A bit is like a switch; it can either be on or off. If it is on then a 1 will be seen. If it is off then a 0 will be seen. The numbers in the squawk code are represented by 1's and 0's.
- The highest number that can be represented by three Binary bits is seven.
- The Special Identification Pulse or SIP is added to the end of the framing pulse when the ident button is pressed on request from ATC and is 4.35µs wide



Emergency Codes

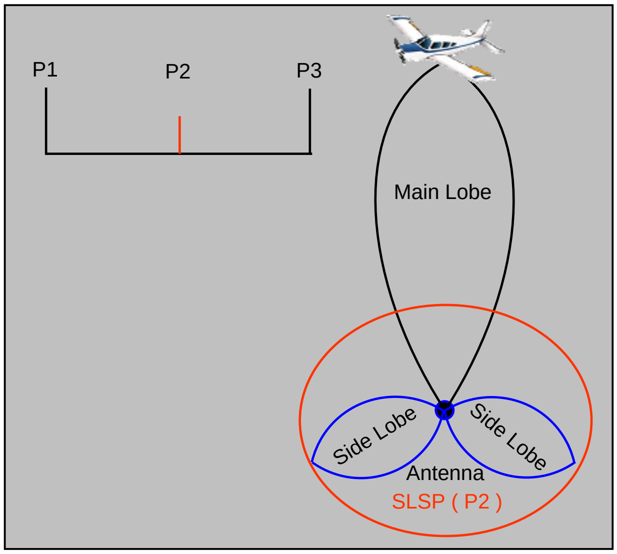
There are three emergency codes that can be used on the Transponder. These codes must be used with care, as they will alert ATC if there is a problem and false alarms are not desirable. It is good airmanship to place the Transponder in Standby before changing the squawk code so as not to accidentally select these codes. The following codes are used:

- **7500**: Used in the event of an aircraft hijack.
- **7600**: Used in the event of radio communication failure.
- **7700**: Used in the event of an emergency situation onboard the aircraft.

Secondary Surveillance Radar Errors

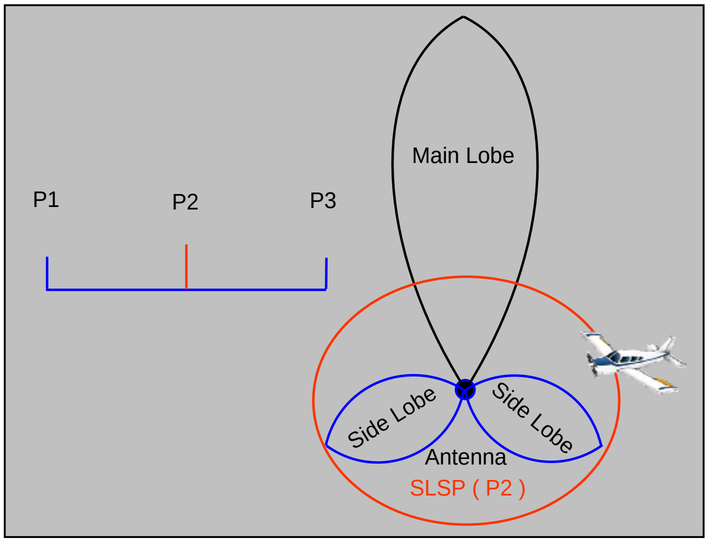
Side Lobe Suppression

An unavoidable property of the radar antenna is that there are smaller subsidiary beams transmitted in addition to the main beam. These subsidiary beams are called Side Lobes. The Side Lobes will give incorrect range and bearing information to the ATC if the main beam is not directed at the aircraft and must therefore be compensated for. The main beam transmits two framing pulses known as the P1 and P3 pulses. 2 µs after the transmission of the P1 and P3 pulses a P2 or a Side Lobe suppression pulse is transmitted. The P2 pulse is omni- directional, is of a known value and is smaller than the main beam. When the aircraft is interrogated by the main beam the P1 and P3 pulses will be larger than the P2 pulse and is therefore a valid interrogation and will be displayed on the radar.



If the aircraft is interrogated by a Side Lobe, the P2 pulse will be larger than the P1 and P3 pulses. This will be an invalid interrogation and will not be displayed on the ATC radar

Side Lobe Suppression



De-fruiting

All SSR stations operate on the same frequencies i.e. 1030 MHz and 1090 MHz. An aircraft Transponder may be interrogated by two ground stations at the same time and reply to both stations. A station may receive a reply meant for another station. Unwanted replies are called fruit and are removed by de-fruiting circuits.

Garbling

This error is caused by aircraft less than 1 nautical mile apart appearing as one target. This error is removed by Killer circuits in the decoder equipment

WORKSHEET 7

SSR

1. Side lobe suppression in SSR is accomplished by:

   (a) defruiting, which removes unwanted replies from aircraft by the use of killer circuits;
   (b) Aircraft close to the transmitter selecting LO sense on the receiver;
   (c) Transmission of a third omni-directional pulse weaker than the main pulses but stronger than the side lobe pulses.

2. An aircraft using a SSR transponder will transmit an IDENT pulse:

   (a) When requested by ATC only;
   (b) When changing codes;
   (c) On initial contact with ATC.

3. The range of SSR is:

   (a) 100nm;
   (b) 200nm;
   (c) 400nm.

4. The airborne SSR transponder recognises an invalid interrogation with a 8 micro-second time interval between P1 and P3 pulses is the aircraft's:

   (a) Allocated code;
   (b) Allocated mode;
   (c) Altitude.

5. An airborne SSR transponder recognises an altitude reporting request by the ground transmitter by comparing the:

   (a) Time intervals between the P1, P2 and P3 pulses;
   (b) Time intervals between the P1 and P3 pulses;
   (c) Relative amplitude of the P1, P2 and P3 pulses.

6. An airborne transponder recognises an altitude reporting request by the ground transmitter by comparing the:

   (a) Time intervals between the P1, P2 and P3 pulses;
   (b) Time intervals between the P1 and P3 pulses;
   (c) Relative amplitude of the P1, P2 and P3 pulses.

7. The airborne SSR transponder reply to a Mode A interrogation is:

   (a) Two framing pulses 20.3 us apart;
   (b) 12 pulses transmitted between two framing pulses;
   (c) Between 0 and 12 pulses transmitted between two framing pulses.

8. Two radio/radar facilities that share a common frequency band are:

   (a) DME and SSR;
   (b) GPS and VDF;
   (c) VOR and DME.

Chapter 12

Radio Altimeter

Radio Altimeter is an electronic method of indicating continuous height of the aircraft above the terrain directly below it. Radio Altimeter measures height from 0 feet to 2500 feet. Radio Altimeter information is used to supply the Auto Pilot Computers with height information for Auto Land capability and height information for the Ground Proximity Warning System.

Summary for Radio Altimeter

Frequency

The Radio Altimeter operates in the Super High Frequency SHF band at 4300 MHz ± 50 MHz. The carrier wave is Frequency Modulated at 20 Hz per Nano second, 50 MHz either side of the centre frequency of 4300 MHz.

Transmission

The Radio Altimeter transmits a vertical Frequency Modulated continuous carrier wave. The Radio Altimeter uses the principal of Frequency Modulation to calculate height information.

Range

0 feet to 2500 feet height information.

Accuracy

The Radio Altimeter is very accurate in the range of 1 foot or 3% of the height, whichever is greater.

Errors

There are two errors that must be taken note of, they are as follows:

- Fixed Error: On the indicator the pointer moves in 5-foot increments, so an error of 2.5 feet can occur as the pointer is between two increments.

- Mushing Error: Mushing errors are caused by the aircraft attitude. If the aircraft is not in level flight, the two antennas are not at the same height above ground and an error of approximately 5 foot can occur.

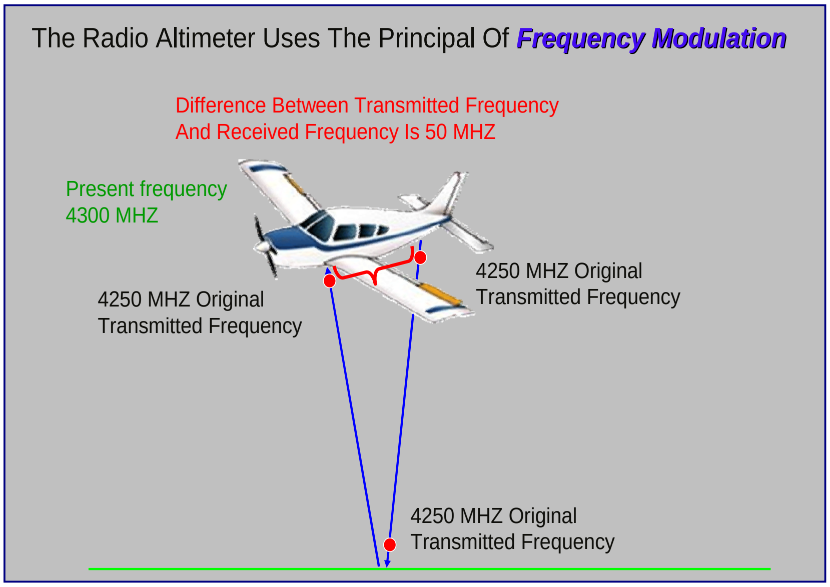
Aircraft Equipment

There is no selection panel for the Radio Altimeter, only an indicator. Radio Altitude is automatically indicated if the equipment is functioning. When the aircraft is out of range of the Radio Altimeter i.e. above 2500 feet the pointer is hidden behind a blanking plate. No instrument flags are seen unless the system has malfunctioned. The Decision Height DH Bug is used to set the minima for CAT II or CAT III ILS approaches. When the aircraft reaches the set minima then the DH light will illuminate.

Principle of Operation

The Radio Altimeter uses the principal of Frequency Modulation to calculate the height of the aircraft. The Radio Altimeter calculates the time taken for a radio wave to travel to the ground directly below the aircraft and back by measuring the change in frequency. The Radio Altimeter transmits a radio wave toward the ground. At the start of the transmission the frequency will be 4250 MHz, known as the original frequency. As the radio wave travels toward the ground, the transmitting frequency changes at the aircraft at a constant rate i.e. 20 Hz per Nano second. When the original transmitted frequency arrives back at the aircraft, it will be different to the frequency being transmitted at the present time.

As the Radio Altimeter has a constant rate of frequency change and now knows by how much the frequency changed, it can calculate the time that the original frequency was away from the aircraft. This time is equal to twice the aircraft height as the radio wave travelled from the aircraft and back. The division is made and the height is displayed on the indicator. This process of operation is continuous and height is continuously displayed.



Radio Altimeter Calculation

What height will be indicated by a Radio Altimeter with the following data; transmitting frequency is 4250.0234 MHz, receiving frequency is 4250.0000 MHz and the Radio Altimeter has a rate of frequency change of 20 Hz per Nano second?

$$\text{Range} = \frac{\text{Speed} \times \text{Time}}{2} \qquad \text{Time} = \frac{\text{Change Of Frequency}}{\text{Rate Of Change Of Freq}}$$

$$\text{Range} = \frac{3 \times 10^{8}\ \text{Meters/ Sec} \times 0.00000117\ \text{Sec}}{2}$$

$$\text{Time} = \frac{23400\ \text{HZ}}{20 \times 10^{9}\ \text{HZ / Sec}}$$

$$\text{Range} = \frac{351\ \text{M}}{2}$$

$$\text{Range} = 175.5\ \text{Meters} \quad \text{Or} \quad 575\ \text{Feet} \qquad \text{Time} = 0.00000117\ \text{Seconds}$$

WORKSHEET 8

Radio Altimeter

1. The principle of operation of the Radio Altimeter is:

    (a) Frequency modulation;
    (b) Amplitude modulation;
    (c) Pulse modulation.

2. A frequency modulated continuous wave radio altimeter operates at a mean frequency of 4300 MHz. The limit of the modulations is:

    (a) 50 to 60 MHz;
    (b) 1100 to 120 MHz;
    (c) 1200 to 250 MHz.

3. Frequency modulated continuous wave radio altimeter errors are:

    (a) Instrument and mushing errors;
    (b) Instrument and fixed/step errors;
    (c) Mushing and fixed/step errors.

4. A radio altimeter indicates the height above the ground of the:

    (a) Aerials;
    (b) Main landing gear;
    (c) Pressure altimeter static vent.

5. A radio altimeter measures the height of the aircraft above the ground by:

    (a) Time difference between the transmitted and received signals;
    (b) Frequency difference between the transmitted and received signals;
    (c) Phase difference between the transmitted and received signals.

    Beam width 3°

    The height of the top of the cloud is:

    (a) 18 500 feet;
    (b) 20 500 feet;
    (c) 23 300 feet.

Chapter 13

Airborne Search Radar (ASR)

Airborne Search Radar or Weather Radar is a Primary Radar system that is used to give a pilot a pictorial presentation of any cloud formations ahead of the aircraft. Cumulo Nimbus cloud formations are dangerous to aviation due to severe turbulence and hail in those types of clouds. Weather Radar is designed to reflect radio energy off water droplets and will indicate where severe weather activity is in the cloud formation. The information is displayed on a Cathode Ray Tube or on the Navigation Displays on glass cockpit aircraft.

Summary for Airborne Search Radar ASR

Frequency of Operation:

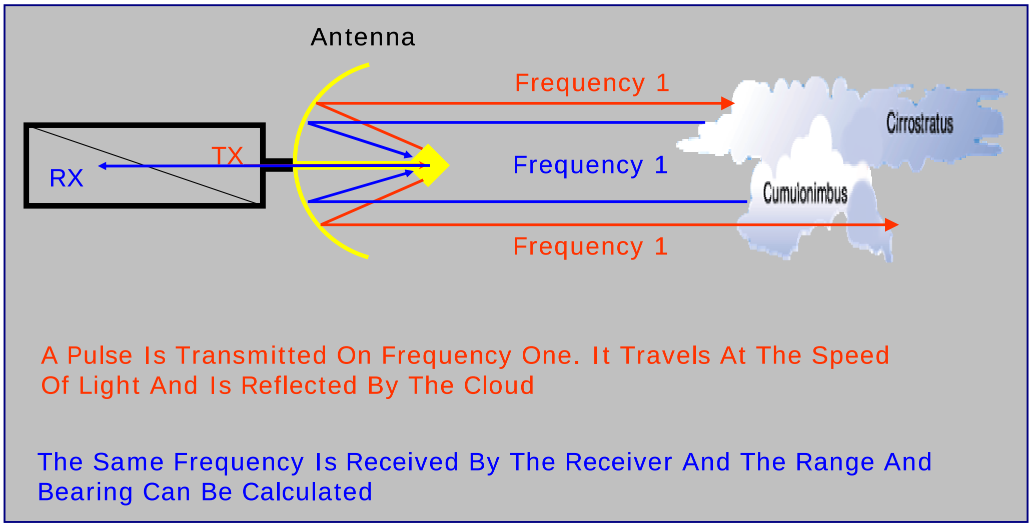
The Airborne Search Radar operates on a frequency of 9.375 GHz, which is in the Super High Frequency SHF band. This frequency is used as it produces a wavelength of 3.3 centimetres, which is the optimum wavelength to reflect off water droplets in cloud formations.

Range

As seen in the first chapter range is dependant on power output. The output of an Airborne Search Radar is extremely high in the region of 160 thousand watts. The maximum range of the radar is also dependant on the PRF and the minimum range on the PW. To double the range of an Airborne Search Radar the power must be increased sixteen fold. Use of the radar on the ground is permitted with caution.

Principle of Operation of the Airborne Search Radar ASR

Airborne Search Radar is a Primary Radar. The transmitter transmits a narrow beam radio wave pulse which travels at the speed of light, 300 000 000 meters per second. The radio energy is reflected off water droplets in cloud formations and some of this energy arrives at the receiver. The time it took the radio energy to travel is measured by the radar system. As the speed of light is constant and the time is known the distance can be calculated. It must be noted that the time interval is the time it took the radio energy to travel from the aircraft and back and must be divided in half for the calculation.



Aircraft Equipment

Radar Antenna

The Radar Antenna or Scanner Unit is located in the nose of the aircraft and consists of a Parabolic Dish with a centre di-pole. The antenna transmits a narrow conical circular pencil shaped beam, with a beam width of approximately 5 degrees. The antenna scans approximately 120 degrees either side of the fore-aft axis of the aircraft. The antenna is also gyroscopically stabilised to keep the centre of the antenna on the horizon regardless of pitch and roll of the aircraft. There is also a tilt function, which mechanically tilts the antenna up or down.

Display Unit

This is normally a CRT screen located on the centre console. The CRT can display varying range markings and bearing lines between 10 and 15 degrees apart for the pilot to estimate range and bearing of the cloud formation from the aircraft. The height of the cloud formation must be calculated.

Control Unit

Most Weather Radar control units have a few common functions on them, amongst other more complex features. The common controls and functions will be discussed.

Control Unit Functions

Range Switch

This rotary switch is used to select different ranges at which the radar can detect cloud formations. On the 300 nautical mile range cloud formations can be seen at distance but not much detail can be seen. At 50 nautical mile range cloud formations can only be detected to 50 nautical miles, but much more detail can be seen. The pilot will select the appropriate range for the weather conditions encountered.

Standby Switch

This function switch places the radar transmitter into Standby Mode. In this mode the radio is powered but the transmitter is not transmitting. This function is activated during the pre-flight to enable the radio components and high power oscillators to warm up and stabilise. If this is not done the radar will take some time before any weather information can be received. This may prove disastrous if the aircraft is flown into adverse weather.

Weather Mode

In this mode the radar is transmitting and receiving through the antenna and weather information will be received by the pilot. In this mode the radar transmits a Conical Pencil Beam. There is also a function called Sensitivity Time Control STC; this allows the sensitivity of the receiver to increase with time to allow all cloud formations to be compared on equal terms. Because of attenuation, the power of a radio wave reduces with distance; this will result in distant clouds, even if they are large, appearing as small returns. STC will prevent this distortion. In Weather Mode a height ring is sometimes seen as a result of overspill of radio energy reflected from the ground directly below. An Aircraft at 35000 feet will produce a height ring of approximately 5 nautical miles.

Map Mode

This mode is used to map the ground. The beam has an angle of 85 degrees in the vertical plane and 3.5 degrees in the horizontal plane. In Map Mode the radar produces a Cosecant Squared Beam so that similar objects are shown at the same brilliance regardless of range. The range of a Map Mode Beam is approximately 65 nautical miles.

Tilt Switch

This switch is used to manually tilt the antenna up or down from the stabilised horizontal position. This function is used to calculate the height of cloud tops. The tilt function will operate even if the gyroscopic stabilisation is off. The tilt control may also be used to tilt the radar antenna down to map the ground at a longer range. However, the resolution of the image is not as good as in Map Mode but the range is further.

Gain Control

Manual Gain Control is used to control the sensitivity of the receiver. This function is used when the preset position does not give an adequate picture. If the gain of the receiver is increased the receiver becomes more sensitive and smaller cloud formations will be seen. If the gain is reduced the receiver becomes less sensitive and then large dangerous clouds can be seen through heavy precipitation.

Stab On / Off

If the automatic gyroscopic stabilisation fails the radar will shut down so as not to destroy the antenna. In this situation the Stab switch is placed to OFF. This will lock the centre of the antenna to the fore-aft axis of the aircraft and weather information will be received. In this position there is no compensation for pitch and roll of the aircraft.

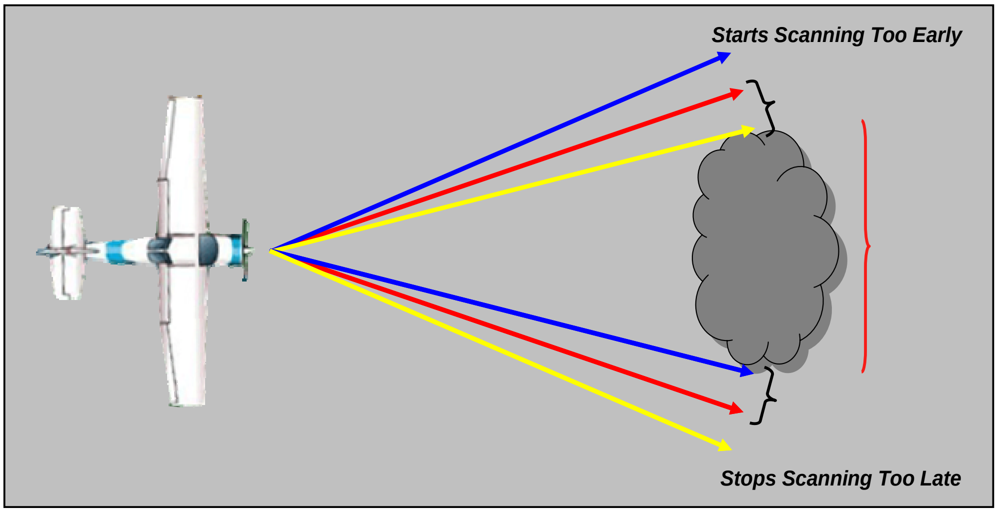
Contour Mode

This function is not found on colour radar systems as the intensity of the cloud formations are shown in colour. On monochrome radar systems this function is used to show areas of severe precipitation and turbulence. When this mode is selected the radar produces an Iso Echo display in which areas of severe turbulence and precipitation are shown as hollow black areas in the cloud formation returns on the CRT. This function is effective up to 50 nautical miles.

Display Distortions

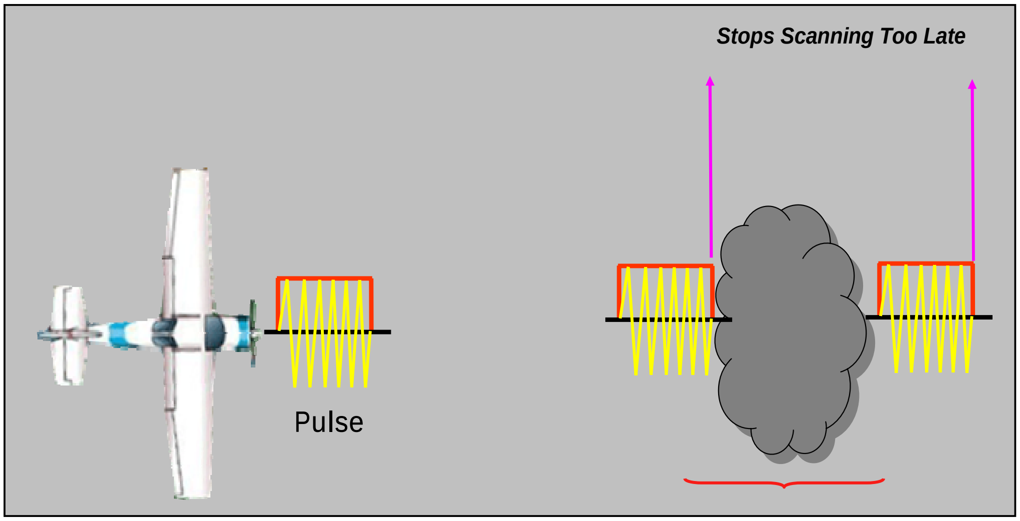
Effect of Beam Width

The beam width of the radar beam adds one half of the beam width to either side of the cloud making it look wider than what it actually is. The beam width is an angular measurement and the distance error will increase with range.



Effect of Pulse Width

The width of the transmitted pulse will add the full pulse width to the cloud depth effectively making the cloud look broader than what it actually is. As the pulse has to travel to the cloud and back to the aircraft, the time is divided by two. This will result in half the pulse width being displayed.

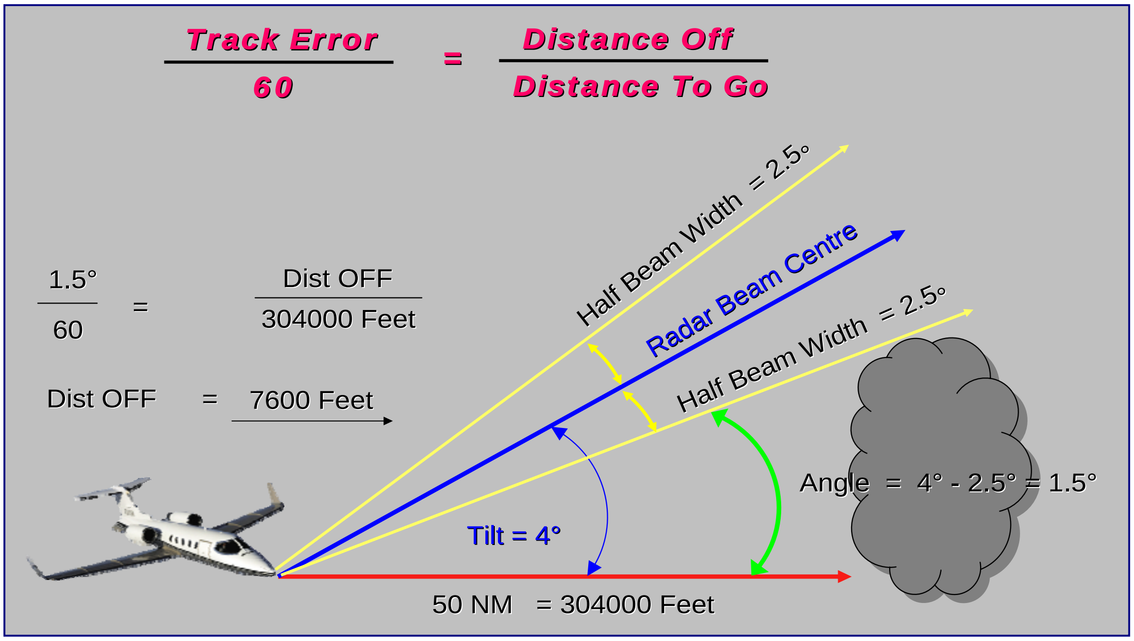


Calculating the Height of Cloud Tops

The height of the cloud is calculated by tilting the weather radar beam up until the cloud image on the CRT disappears, or down until the cloud image on the CRT just appears. The base of the beam will then just touch the cloud. Using the One-In-Sixty Rule or trigonometry the height can be calculated. The purpose of calculating the height of the cloud is to calculate how many miles to deviate around the weather to avoid the anvil of a thunderstorm.

Example No 1

Calculate the height of the cloud top above the aircraft if the beam width of the radar beam is 5 degrees and the tilt is at 4 degrees up. The aircraft is 50 nautical miles from the cloud.

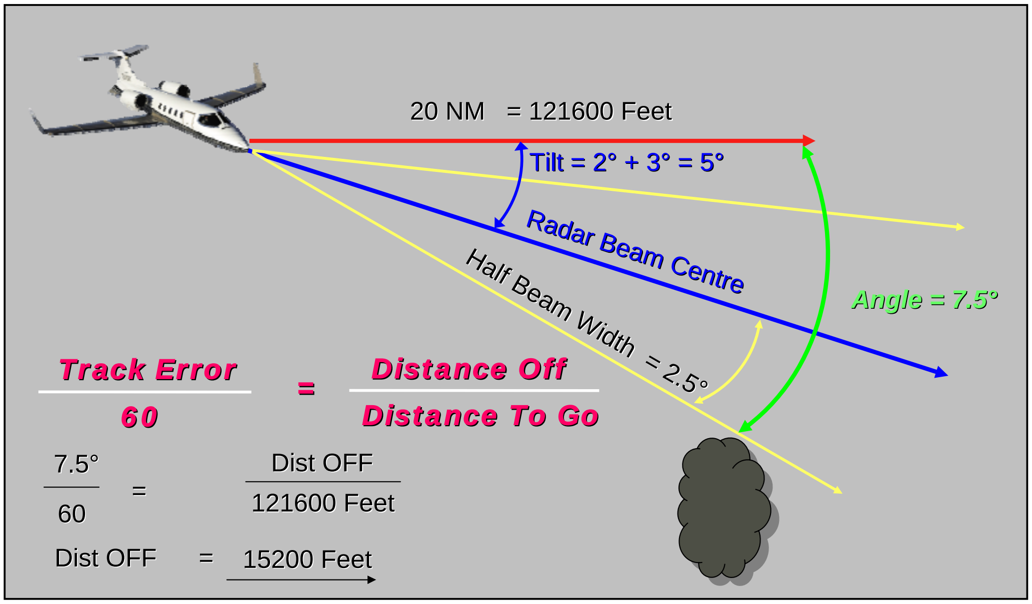


Notes on the Calculation

- It must be noted that the beam width of the radar beam is touching the cloud.
- The angle that is used in the calculation is between the beam width touching the cloud and the horizontal plane.
- The tilt angle is between the centre of the antenna and the horizontal plane.
- It must also be noted that all the mathematical units must be converted into the same units i.e. the 5 nautical miles is converted into feet.
- The height of the cloud above the ground could be asked, in which case the aircraft height must be added to the cloud top height.

Example No 2

Calculate the height of the cloud top below the aircraft if the beam width of the radar is 5 degrees, the tilt is at 2 degrees down and the aircraft is at 20 nautical miles from the cloud. The gyroscopic stabilisation is off and the deck angle is 3 degrees nose down.



Notes on the Calculation

- It must be noted that the beam width of the radar beam is touching the cloud.
- The angle that is used in the calculation is between the beam width touching the cloud and the horizontal plane.
- The tilt angle is between the centre of the antenna and the horizontal plane.
- It must also be noted that all the mathematical units must be converted into the same units i.e. the 5 nautical miles is converted into feet.
- The height of the cloud above the ground could be asked, in which case the aircraft height must be subtracted to the cloud top height.

WORKSHEET 9

AWR

1. Weather radar operates in the SHF band because:

   (a) Narrow beams can be transmitted only on SHF;
   (b) The short wavelengths produced by SHF give excellent reflections from large water drops in cloud;
   (c) The scanner dish required by SHF is small and can fit into the nose of an aircraft.

2. When using weather radar to map a coastline the conical pencil beam should be used in preference to the cosecant beam:

   (a) At ranges of less than 50 nautical miles;
   (b) At ranges greater than 60 nautical miles;
   (c) Over a calm sea.

3. Operation of weather radar (ASR) on the ground:

   (a) Is prohibited;
   (b) May be used in maintenance areas only;
   (c) May be used with extreme caution.

4. The iso-echo contour system of the weather radar (ASR):

   (a) Indicates the areas in a cloud where severe turbulence may be encountered;
   (b) Reduces the receiver sensitivity as the aircraft approaches a cloud;
   (c) Indicates the areas where cloud penetration is advisable.

5. An aircraft is climbing through 6500 feet.

   Attitude director 4° pitch up
   Weather radar stabilizer off
   Cloud range 27 nautical miles
   Tilt control 3° up
   Beam width 5°

   The height of the top of the cloud is:

   (d) 15 000 feet;
   (e) 17 000 feet;
   (f) 19 000 feet.

6. Airborne weather radar displays suffer from distortion due to:

   (a) As the beam width increases with range a cloud appears to be twice its size;
   (b) A cloud reflects an echo for the time duration of the pulse, and as the CRT timebase is halved the cloud appears half its size;
   (c) On the CRT the beam adds one half of the beam width on either side of the cloud.

7. Airborne weather radar displays suffer from distortion due to the length of the time base on the CRT being half the pulse travel time:

   (a) Making a cloud appear smaller than its actual size;
   (b) Thus extending the cloud size by one half of the pulse length;
   (c) Reducing the range of the cloud by one half of the pulse length.

8. Super High Frequency (SHF) is used by:

   (a) Weather Radar;
   (b) DME;
   (c) SSR.

9. The function of the weather radar iso-echo display is:

   (a) To indicate areas where cloud penetration is advisable;
   (b) To indicate areas in cloud where extreme turbulence exists;
   (c) For ground mapping.

10. An aircraft is cruising at FL 390.

    Attitude director 1° pitch up
    Weather radar stabilizer off
    Cloud range 51 nautical miles
    Tilt control 3° down
    Beam width 3°

    The height of the top of the cloud is:

    (a) 18 500 feet;
    (b) 20 500 feet;
    (c) 23 300 feet.

Chapter 14

Area Navigation (RNAV)

An Area Navigation or RNAV system provides a means of straight-line navigation using ground-based stations such as VOR and DME. Area Navigation uses the principal of Rho Theta navigation. Rho is considered to be a distance measured from the VOR station and Theta is the bearing from the station or the radial from the station. By obtaining a distance and a bearing, a fix can be plotted.

Area Navigation Terminology

Waypoint

A waypoint is a geographical location defined by a bearing and distance or a Latitude and Longitude. Area Navigation uses waypoints to define a specific route entered by the pilot.

Course Line Computer CLC

This is the computing module of the Area Navigation system. This computer uses trigonometry to solve simple triangles and to plot a phantom station at the required waypoints.

The trigonometry is referred to as the Sine and Cosine Rule.

Slant Range Error

Area Navigation uses DME information to calculate distance, and as seen in the DME chapter there is a difference between the ground range and slant-line range. This error is known as Slant Range Error.

DME Slant Range Corrector

Simpler RNAV computers or Course Line Computers CLC do solve the slant range error. However, the more advanced CLC's are supplied with aircraft altitude and VOR / DME elevation allowing the ground distance to be calculated.

Change Over Point

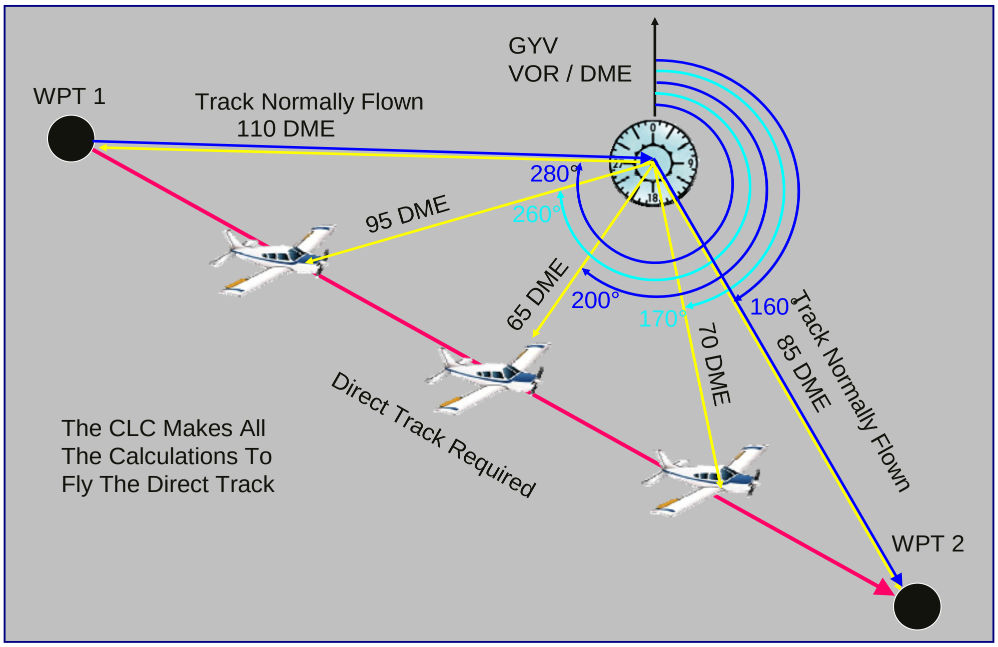
This is a point, which may be a waypoint, where the Area Navigation computer changes from one navigational aid to another navigational aid.

Area Navigation Symbology

A four-point star is the symbol used to indicate a waypoint. A waypoint co-located with a VORTAC has a circle with a dot inside the four-point star.

Principle of Operation

Once the pilot has selected the required route, the information is entered into the CLC. A waypoint is established by entering the distance of the waypoint from the VOR and the bearing or radial from the VOR on the CLC control panel. The CLC will then create a phantom station at that waypoint, so it would appear as if one is flying to a VOR station. The CLC will compute the magnetic track to the phantom waypoint. Any deviation left or right of the track will be displayed on the Course Deviation Indicator. Distance to the waypoint will be shown on the CLC control panel. The CLC will compute and solve the triangle continuously and supply continuous deviation information on the CDI. It must be noted that information on the CDI changes notation from angular deflection to displacement left or right of the required track, depending on the distance from the VOR station and next waypoint. This will be discussed in the CDI deviations later in this chapter.



Course Deviation Indicator CDI

The CDI is used by the VOR and RNAV radio systems. Deviations for the RNAV system are as follows:

- Full-scale deflection of the deviation bar further than 100 nautical miles from the waypoint is equal to 10 degrees.
- Full-scale deflection of the deviation bar closer than 100 nautical miles from the waypoint equals 5 nautical miles.
- Full-scale deviation in approach mode i.e. closer than 25 nautical miles from the destination waypoint is equal to 1.25 nautical miles.

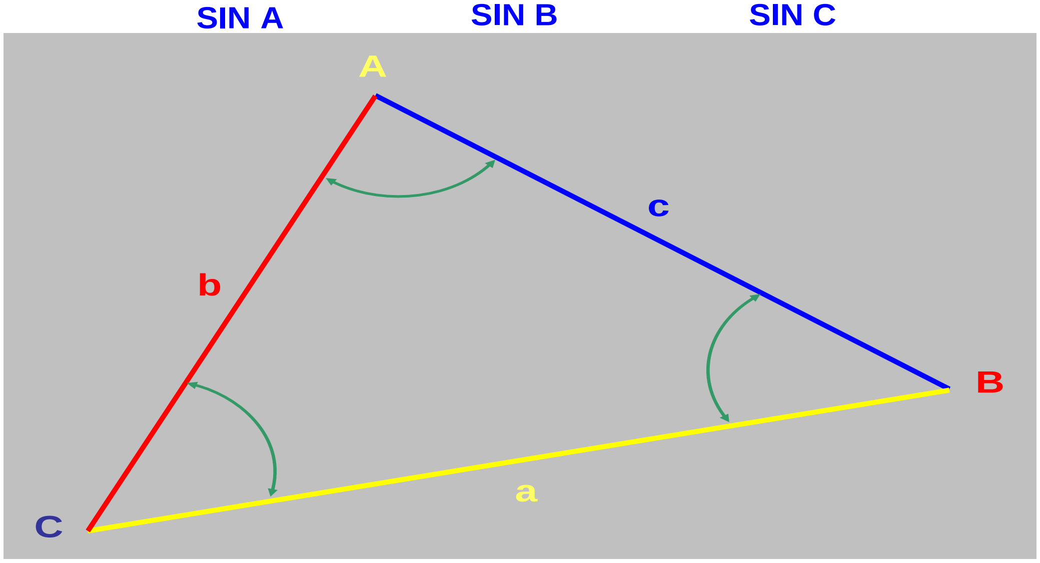
Course Deviation Indicator CDI

Area Navigation Calculations

The RNAV triangle does not always have a 90 degrees angle. Therefore, the normal trigonometric functions will not apply. The following formulae are used to solve the RNAV calculations:

Sine Rule Used for Magnetic Track

$$\frac{a}{\text{SIN A}} = \frac{b}{\text{SIN B}} = \frac{c}{\text{SIN C}}$$



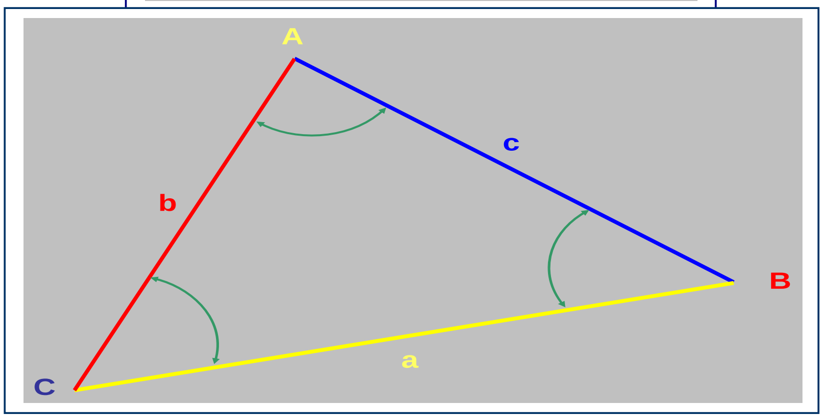
Area Navigation Calculations

Cosine Rule Used for Distance

$$a^2 = b^2 + c^2 - 2bc \times \cos A$$

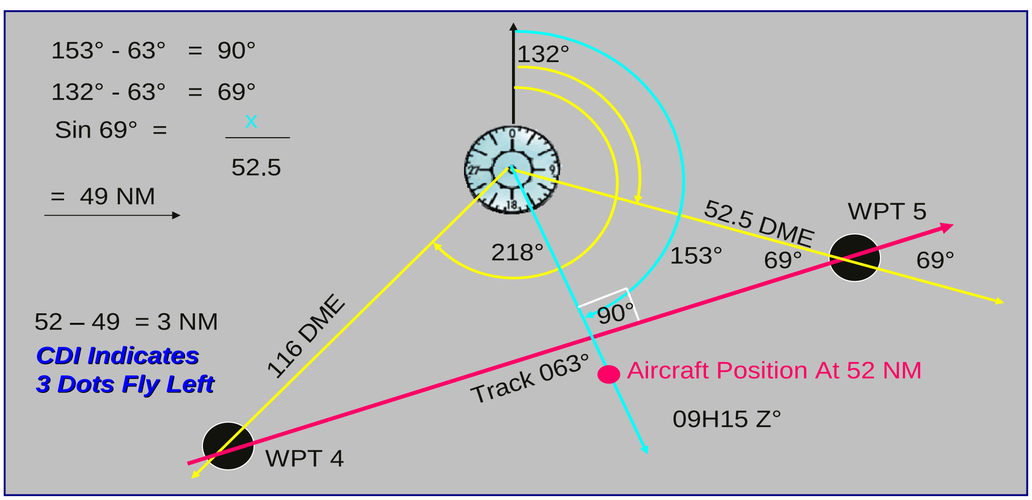
$$b^2 = a^2 + c^2 - 2ac \times \cos B$$

$$c^2 = a^2 + b^2 - 2ab \times \cos C$$



Example No 1

An aircraft flying from waypoint four, which is defined by the 218 degree radial at DME distance of 116 nautical miles, to waypoint five, which is defined by the 132 degree radial at DME distance 52.5 nautical miles. The aircraft is flying a track of 063 degrees magnetic. At 09H15 Zulu the aircraft is on radial 153 degrees from the VOR and at a DME distance of 52 nautical miles. What would the indication on a five dot CDI be?



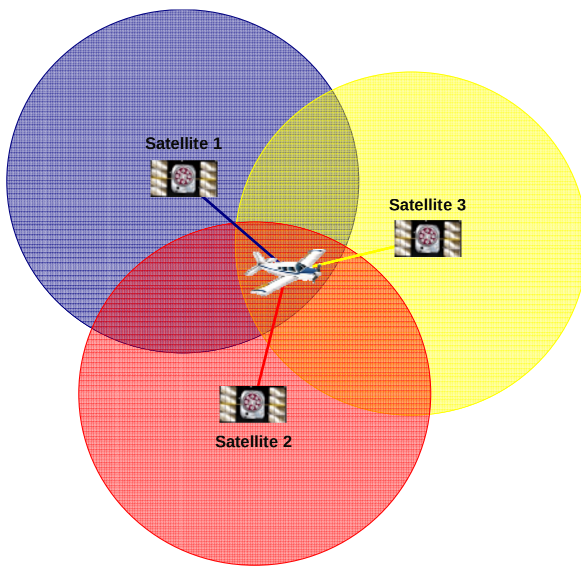
Chapter 15

Global Positioning System (GPS)

Global Positioning System is a space-based radio navigation system delivering accurate three-dimensional position fixing, velocity and time. The information is continuously available and provides worldwide coverage.

Principle of Operation

Global Positioning System uses the principal of time measurement from when the radio wave is transmitted from the satellite to when the radio wave is received by the receiver in the aircraft. As the speed of a radio wave is known and the time is measured, the distance of the receiver from the satellite can be calculated using the formula “distance is equal to speed multiplied by time”. This distance from the satellite is represented by the radius of a sphere on which the receiver must be positioned. If the information of four satellites is used, they produce an intersection point where the receiver and thus the aircraft must be positioned.



The Global Positioning System GPS

The GPS system consists of three segments, they are as follows:

- Space Segment.
- Ground Segment.
- User Segment.

Global Positioning System Space Segment

Space Segment

The Space Segment consists of the following components:

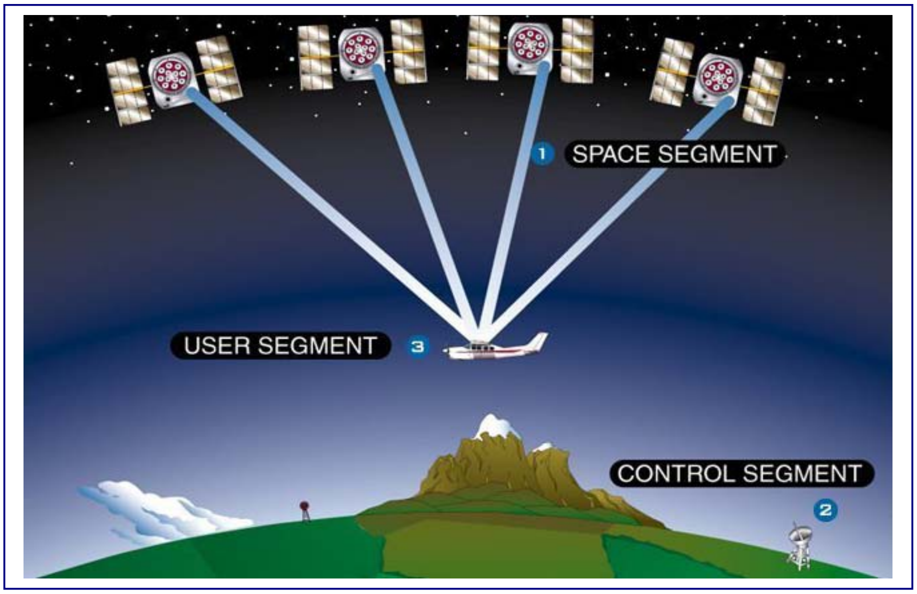
- Twenty-four satellites in the constellation.
- Twenty-one are operating and three are on standby.
- One orbit takes approximately twelve hours.
- The radius of the orbits is approximately 20,200 kilometres and takes twelve hours to complete.
- There are six orbital planes at 55 degrees to the equator and spaced at 60 degrees apart.

Control Segment

- The Control Segment consists of five unmanned ground monitoring and tracking stations.
- The master tracking station is in Colorado Springs.
- The control stations monitor the onboard clocks, two Caesium clocks and two Rubidium clocks, and the orbital data of the satellites.
- Any corrections are sent to one of four stations and transmitted to the satellites to update Ephemeris and the clock of the satellite every twenty-four hours.

User Segment

- The User Segment consists of the receiver inside the aircraft. The receiver receives four or more satellites and calculates its position.
- No hand held GPS receivers are approved for primary IFR navigation
- The aircraft receiver has a number of built-in databases, one of which is all the information concerning the satellites.



Operation of the Global Positioning System

GPS Transmitting Frequencies

There are two frequencies that the satellites transmit on. They are as follows:

- L1 Band on frequency 1575.42 MHz. This L1 band transmits a Precision Code (P) and is used for military purposes, and a Course Acquisition code (CA) for civilian use.

- L2 Band on frequency 1227.6 MHz. This L2 band transmits a Precision Code (P) for military purposes only.

Each satellite is allocated its own unique Coarse Acquisition (CA) or Precision (P) for identification of the satellites.

Coarse Acquisition Code

The CA code modulates the carrier at 1.023 MHz and takes the form of randomly spaced set of pulses generated for one millisecond. The same set of pulses is repeated every millisecond. It is known as a Pseudo Random Noise Code or PRN Code.

Precision Code

The P code is a 10 MHz PRN code with a seven-day cycle. This code is further encoded into the Y code, which is only available to the US military. The P code is the basis for Precise Positioning Service. The P code is modulated on the L1 and L2 frequencies, which allow for the Ionospheric delay correction, as the two frequencies are affected differently by the Ionosphere.

Navigation Messages

A 50 Hz modulation on the L1 Carrier frequency carries the satellite Ephemeris formula, the clock corrections, the exact time of transmission and the satellite almanac. All the codes are Binary codes and use Phase Modulation to modulate the carrier frequencies.

Selective Availability

The accuracy of the CA GPS signal was controlled by means of jittering the signal. Jittering the signal was achieved by altering the timing of the satellite in a random fashion thereby reducing the accuracy of the information received by the aircraft receiver.

Determination of Range

At the same time that the GPS satellite transmits the CA Code, the GPS receiver generates a copy of the CA code. The CA code generated by the satellite arrives at the receiver a short time later. The GPS then slews or moves its copy of the CA code forward to match the CA code transmitted by the satellite. The amount of slew is proportional to the distance of the aircraft from the satellite.

Operation of the Global Positioning System

Three Satellite Fixing

Three-satellite fixing will only give a two-dimensional fix i.e. position. No height information is available. The velocity of the aircraft is measured by Instantaneous Doppler Shift at the aircraft.

Four Satellite Fixing

Four satellite fixing will give a three-dimensional fix i.e. position and height. The velocity of the aircraft is measured by Instantaneous Doppler Shift at the aircraft.

Satellite Visibility

GPS satellites must be five degrees above the horizon for them to be visible to the receiver. Any satellites below the horizon will be masked or rejected by the receiver, as the error caused by the prolonged propagation through the atmosphere is too great.

Timing Errors

Relativistic Errors

The clock in the aircraft receiver and the clocks in the satellite operate at different speeds due to Einstein's Theory of Relativity and the speeds of objects as compared to the speed of light. The clocks operate at different speeds due to the different gravitational fields. This error can be compensated for.

Ionospheric Errors

As discussed in the first chapter the speed of a radio wave will slow down as it moves from one medium to another denser medium. As the radio wave travels through the Ionosphere it will slow down causing errors in the timing calculations of the GPS receiver and thus a position error. The error is proportional to the square of the transmission frequency.

Tropospheric Errors

The speed of the radio wave slows down when it passes through the Troposphere. This reduction in speed will cause a timing error and a position error at the receiver. The error is greatest when the satellite is low on the horizon and the aircraft is at a low altitude. The Tropospheric error is directly proportional to aircraft altitude.

Differential GPS

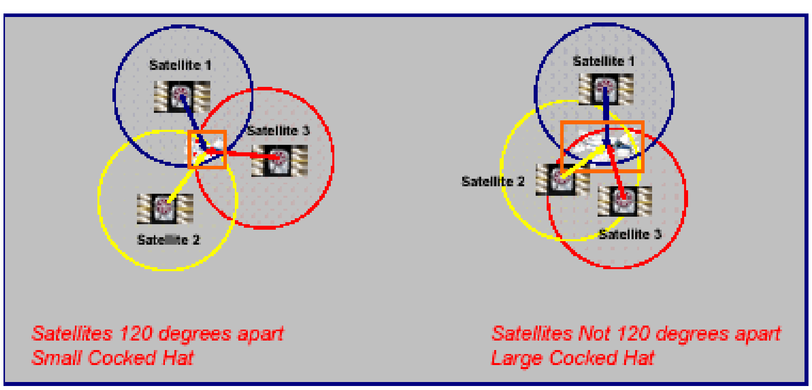
The airport reference point is accurately surveyed and a GPS receiver is positioned at this position. The receiver receives all the transmissions of the GPS satellites and computes the GPS position. The difference between the surveyed position and the position calculated by the ground receiver is computed and the difference is transferred to the aircraft by radio link to update the aircraft receivers.

Receiver Autonomous Integrity Monitoring RAIM

By using four satellites a position can be fixed by the GPS receiver. If, however, one of the satellites is transmitting erroneous information the position calculated by the aircraft receiver will be in error. This error will not be detected until the ground station updates the satellite. This leaves the pilot with an error in navigation. This is not acceptable for primary navigation. By using different combinations of four satellites the position calculations of these combinations can be compared and a faulty satellite can be eliminated. To ensure 100% detection of faulty satellite information there would need to be thirty six to forty two satellites in orbit. For the RAIM module in the receiver to operate there must be a minimum of five satellites visible to the receiver at all times.

Position Dilution of Precision PDOP

Due to the errors involved in the timing of the GPS radio signals discussed above the chances of three or even four of the range radii crossing in the same place are small. This type of position fixing produces an error area called a Cocked Hat. The position of the aircraft is estimated inside this area. The optimal position of the four satellites to reduce the size of the Cocked Hat are three satellites positioned at 120 degrees apart in the horizontal plane and the fourth satellite directly overhead. Any other position of the satellites will increase the area of the Cocked Hat and increase the position error.



Chapter 16

Ground Proximity Warning System (GPWS)

During aircraft accident investigation it became clear that pilot error was responsible for a large number of aircraft accidents. What was even more concerning about these accidents was that in a large number of them the pilots flew a serviceable aircraft into the ground. It became clear that a system was needed that could warn the pilots of close terrain proximity. The Ground Proximity Warning system will in most cases warn the pilot of close terrain proximity. The GPWS has a number of inputs from different aircraft systems and will provide an Alert to the pilot to rectify the problem and in some cases a Warning to the pilot if the situation is not corrected.

Ground Proximity Warning System operation

The Ground Proximity Warning system accepts inputs from the following systems:

- Radio Altimeter input to measure the height of the aircraft above the ground
- Vertical speed Input to measure the aircraft rate of climb or descent.
- ILS Glide Slope receiver to measure Glide Slope deviation.
- Landing Gear Extended switch to alert the pilot that the landing gear is not extended for landing and for different configuration conditions.
- Flap Extended switch to alert the pilot that the flap is not in the landing configuration for landing and for different configuration conditions.

These are the minimum inputs required by the Ground Proximity Warning System. The more sophisticated GPWS systems have a Topographical map databases and can, in conjunction with the aircraft navigation systems predict where high terrain is with reference to the aircraft. They are also capable, in conjunction with the weather radar to measure and warn the pilot of wind shear ahead of the aircraft.

Modes of Operation for the Ground Proximity Warning System

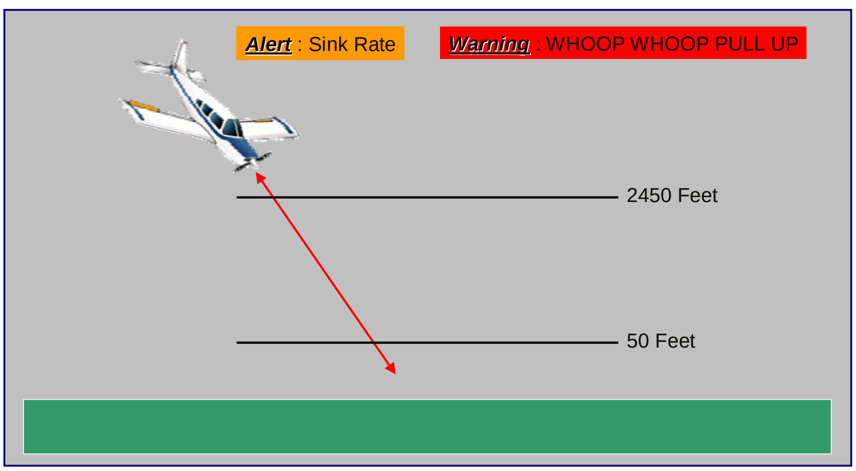
There are seven modes of operation for the Ground Proximity Warning System. In IMC the pilot must respond immediately to the alert call of the Ground Proximity Warning System and correct the flight path of the aircraft. If the flight is in VMC and the pilot can visually confirm that the GPWS is in error the alert and warning call of the GPWS may be ignored but the system must be reported as defective. The seven modes of operation are as follows:

- **Mode 1**: Excessive rate of descent with respect to terrain.
- **Mode 2 A**: Excessive rate of terrain closure and the aircraft is not in the landing configuration.
- **Mode 2 B**: Excessive rate of terrain closure and the aircraft is in the landing configuration.
- **Mode 3**: Negative rate of climb after Take Off or Go Around.
- **Mode 4 A**: Unsafe terrain clearance and the aircraft is not in the landing configuration. The trigger for the GPWS is that the gear is up.
- **Mode 4 B**: Unsafe terrain clearance and the aircraft is not in the landing configuration. The trigger for the GPWS is that the flaps are up.
- **Mode 5**: Excessive downward departure from the Glide Slope during an ILS approach.
- **Mode** 6: Descending below minima.
- **Mode 7**: Wind shear. This is an advanced mode.

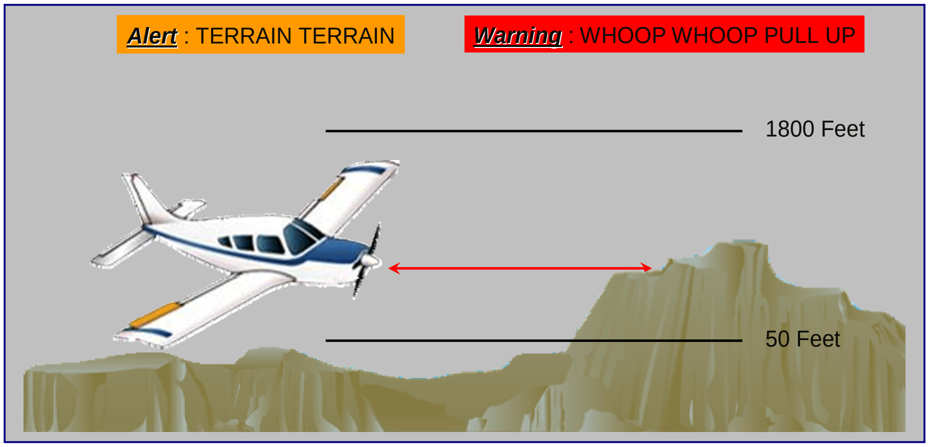
Modes of Operation for the Ground Proximity Warning System

Mode 1

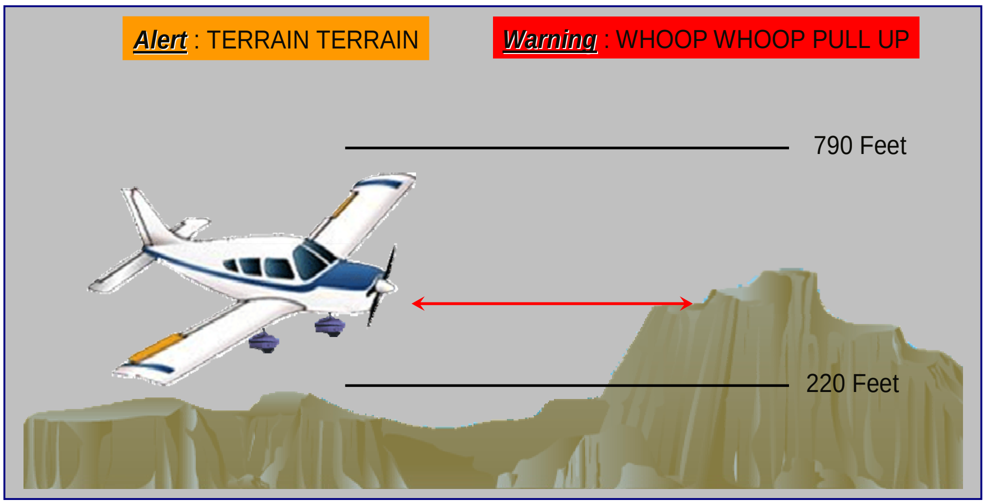
Excessive rate of descent with respect to terrain.



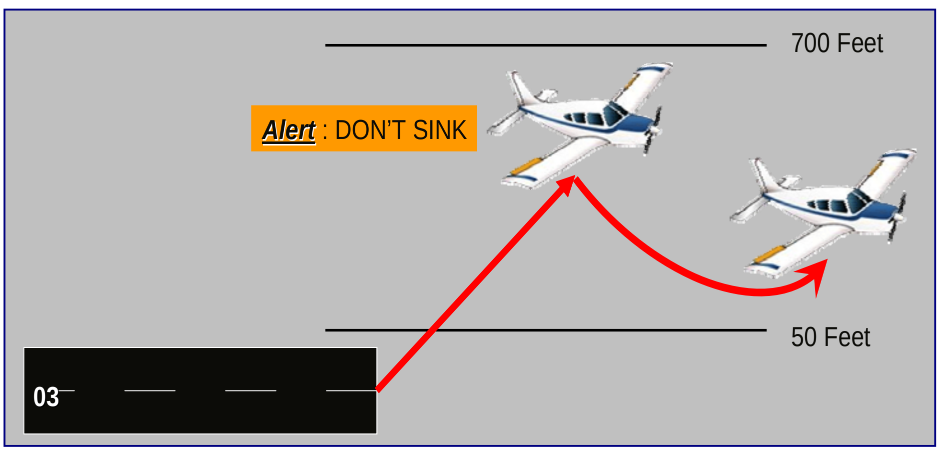
Mode 2 A
Excessive rate of terrain closure and the aircraft is not in the landing configuration.



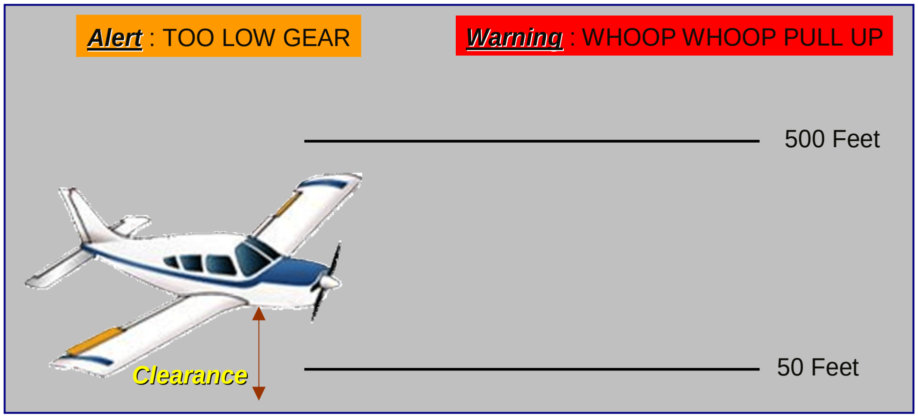
Mode 2 B
Excessive rate of terrain closure and the aircraft is in the landing configuration.



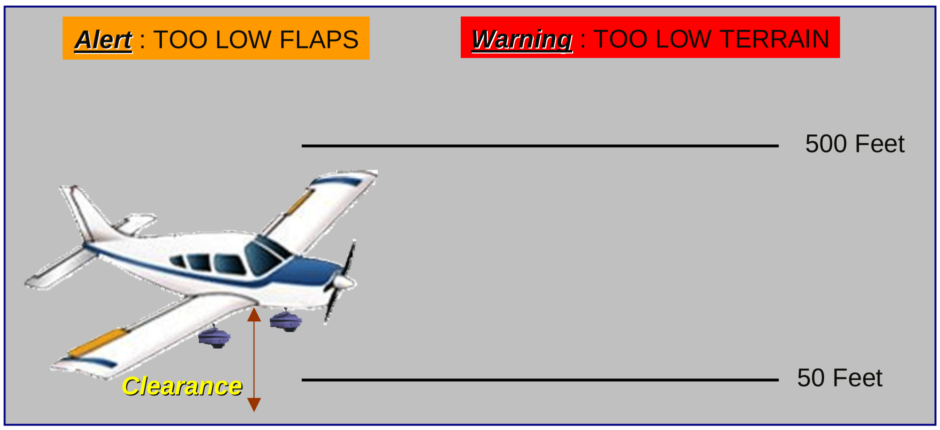
Mode 3
Negative rate of climb after Take Off or Go Around.



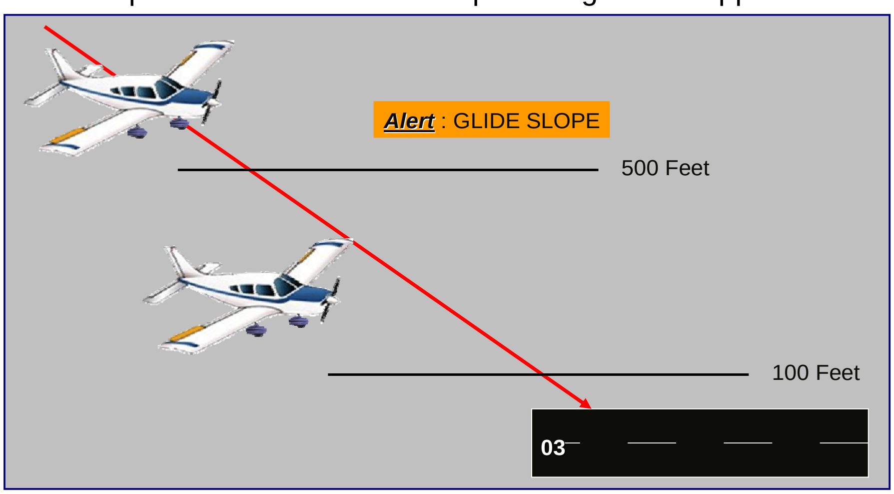
Mode 4 A
Unsafe terrain clearance and the aircraft is not in the landing configuration. The trigger for the GPWS is that the gear is up.



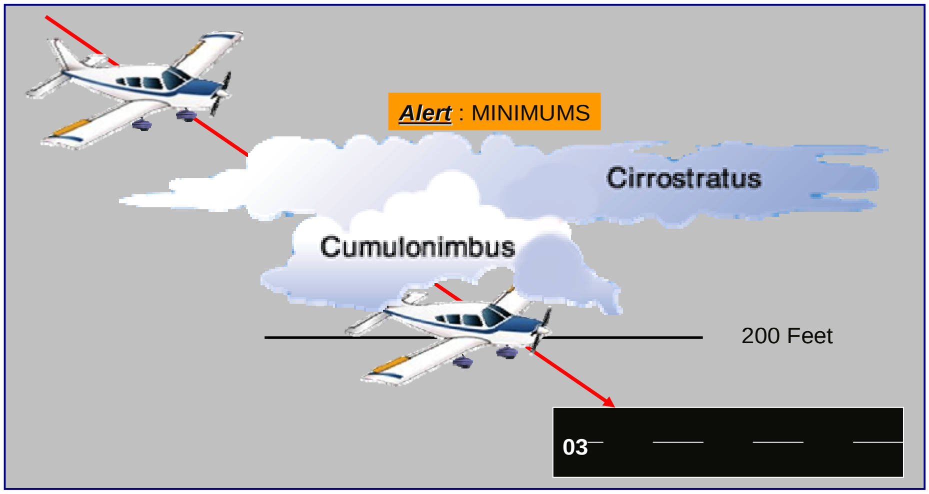
Mode 4 B
Unsafe terrain clearance and the aircraft is not in the landing configuration. The trigger for the GPWS is that the flaps are up.



Mode 5
Excessive downward departure from the Glide Slope during an ILS approach.



Mode 6
Descending below minima.



Chapter 17

EMERGENCY LOCATER BEACON (ELT)

The Emergency Locator Beacon is a self-contained radio transmitter that is located in the rear of the aircraft or in each life raft if the aircraft flies over water. The ELT transmits on the emergency frequencies and will assist in locating the aircraft or raft in the event of a crash.

Principal of Operation

The Emergency Locator Beacon will transmit on dual frequencies when activated. The ELT transmits an Omni Directional signal, which is used to locate the aircraft in distress. The ELT radio beacon is supplied from its own battery power and will transmit through its own whip antenna. The ELT radio beacon will transmit on its own power for approximately fifty hours and is required to transmit continuously. The ELT radio beacon is required to operate in the temperature range of minus 20 degrees to plus 50 degrees Celsius and will activate automatically on a five G or more impact load when armed, or, if in the life raft, will be activated by water.

Frequencies

The ELT radio signal is in the VHF radio frequency band and is line of sight. It has a range of approximately ninety nautical miles and will transmit to an altitude of ten thousand feet.

The transmitting frequencies are:

- 121.5 MHz
- 243.0 MHz

Servicing and Testing

The ELT batteries are replaced every two years or after twenty minutes or more of operation. The ELT is tested every three months by a certified radio technician. The ELT is operated within the first five minutes of the hour on 121.5 MHz by transmitting three pulses.

Chapter 18

TRAFFIC COLLISION AVOIDANCE SYSTEM (TCAS)

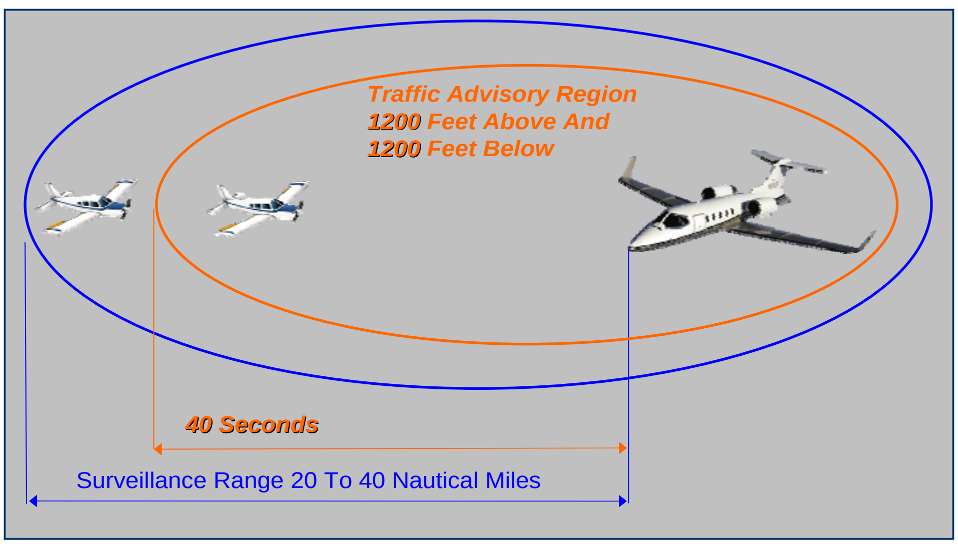
The TCAS is an airborne system that will allow an aircraft to monitor other traffic within twenty to forty nautical miles and within two thousand feet above and below itself. The system will also provide a warning and depending on the proximity of the other traffic the system will also provide advice on collision avoidance in the form of aural commands to fly.

Principal of Operation

The TCAS uses secondary radar in the form of the aircraft TCAS transponders. Collision potential is assessed by the TCAS computers based on the data obtained from the air-to-air interrogations of the aircraft transponders. The system allows measurement of the aircraft tracks, altitudes, ranges and velocities. The searching aircraft is referred to as “Own “ aircraft and the threat aircraft as “ Proximate “ aircraft. The system will provide the pilot with an alert and if deemed necessary by the TCAS computer an action to follow i.e. climb or descend if it considers the threat aircraft a collision potential.

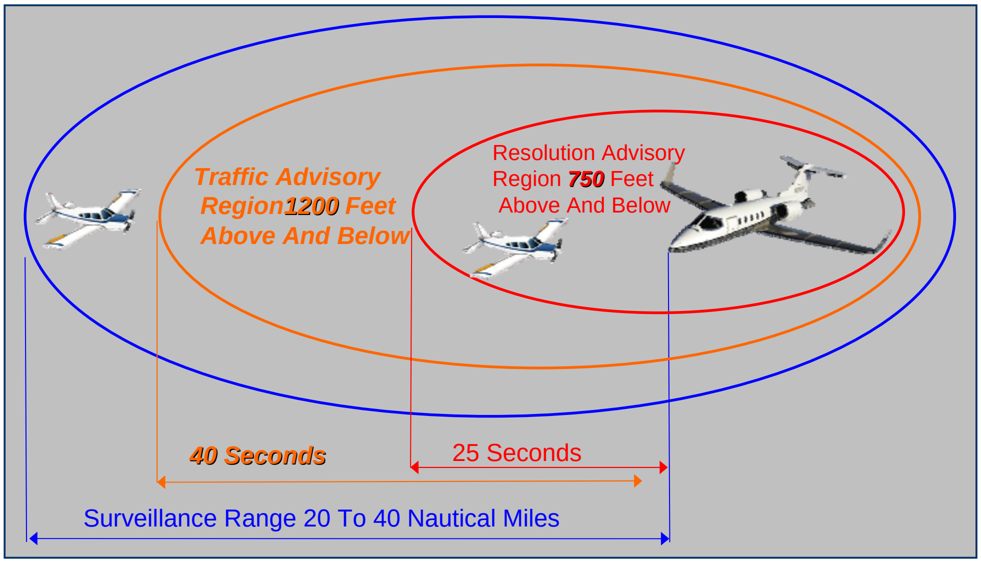
Traffic Advisories (TA)

The hazard of the proximate traffic is expressed as TAU, which is the result of dividing the range between the two aircraft by the range rate to produce an elapsed time before the proximate traffic will collide with own aircraft. It can be seen that the TAU threshold is based on each aircraft speed and when the TAU or elapsed time to collision is forty seconds a warning is triggered. This warning is called a Traffic Advisory or a TA. The crew must not take any avoiding action at this stage but must try and obtain a visual on the proximate traffic. It must be noted that if no altitude data or mode C is available, there will be no warning.



Resolution Advisories (RA)

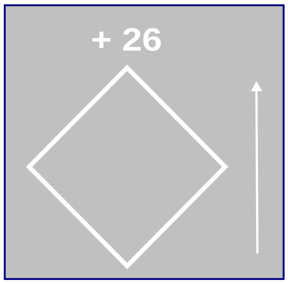
The hazard of the proximate traffic is expressed as TAU, which is the result of dividing the range between the two aircraft by the range rate to produce an elapsed time before the proximate traffic will collide with own aircraft. It can be seen that the TAU threshold is based on each aircraft's speed and when the TAU or elapsed time to collision is twenty five seconds a warning is triggered. This warning is called a Resolution Advisory or a RA. The crew must take avoiding action at this stage in the direction instructed by the TCAS voice. This TCAS instruction overrides any air traffic control instruction at that stage. Once the danger has passed the aircraft must return to the original flight level and inform air traffic control. It must be noted that if no altitude data or mode C is available, there will be no warning.



TCAS Symbology

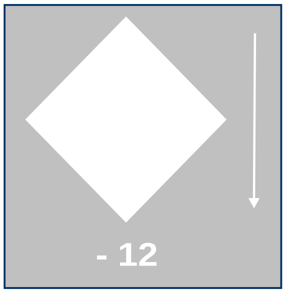
TCAS symbology is displayed to the pilots on different indicators depending what avionics are available inside the aircraft. On aircraft with conventional analogue instruments the TCAS information is displayed on a CRT Vertical Speed Indicator. The TCAS symbology is displayed in the background and the instructions to climb or descend will be displayed on the outer edge of the instrument in the form of a lit green or red band. The pilot must position the VSI pointer inside the green band. On aircraft with EFIS or "glass flight deck" the TCAS information id displayed in the navigation display and instructions to climb or descend are displayed on the primary flight display.

Other Traffic:



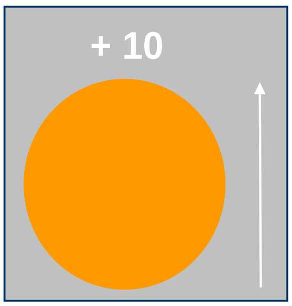
Traffic that does not pose a threat to "Own" aircraft. The number indicates the other traffic's height above the "Own" aircraft in feet i.e. 2600 feet above. If the other traffic is below the "Own" aircraft the number will indicate a negative number i.e. -26 or 2600 feet below the "Own" aircraft. The arrow next to the symbol indicates that the other traffic is climbing at 500 feet / minute or more. If the arrow points downward it is indicating that the other traffic is descending at 500 feet or more.

Proximate Traffic:



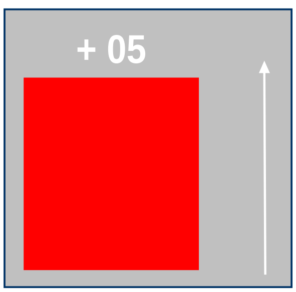
This symbol indicates proximate traffic within six nautical miles and within 1200 feet below or above "Own" aircraft. The number indicates the other traffic's height below the "Own" aircraft in feet i.e. 1200 feet below. If the other traffic is above the "Own" aircraft the number will indicate a positive number i.e. +12 or 1200 feet below the "Own" aircraft. The arrow next to the symbol indicates that the other traffic is descending at 500 feet / minute or more. If the arrow points upward it is indicating that the other traffic is climbing at 500 feet or more.

Traffic Advisory (TA):



This symbol indicates that the intruder is forty seconds from the "Own" aircraft. The number indicates the other traffic's height above the "Own" aircraft in feet i.e. 1000 feet above. If the other traffic is below the "Own" aircraft the number will indicate a negative number i.e. -10 or 1000 feet below the "Own" aircraft. The arrow next to the symbol indicates that the other traffic is climbing at 500 feet / minute or more. If the arrow points downward it is indicating that the other traffic is descending at 500 feet or more

Resolution Advisory (RA):



This symbol indicates that the intruder aircraft is twenty five seconds from the "Own" aircraft and pilot must manoeuvre the aircraft to avoid a collision. The number indicates the other traffic's height above the "Own" aircraft in feet i.e. 500 feet above. If the other traffic is below the "Own" aircraft the number will indicate a negative number i.e. -05 or 500 feet below the "Own" aircraft. The arrow next to the symbol indicates that the other traffic is climbing at 500 feet / minute or more. If the arrow points downward it is indicating that the other traffic is descending at 500 feet or more

Chapter 19

MICROWAVE LANDING SYSTEM (MLS)

Microwave Landing System or MLS is an improved landing system designed to replace conventional ILS but was abandoned in favour of GPS systems approaches. However, GPS is not yet approved for primary IFR approaches. The frequencies of the Azimuth and Elevation Beams are between 5031 MHZ and 5090 MHZ and are in the Super High Frequency band.

Principal of Operation

Microwave Landing Systems allow approaches to be made from any direction within the system's horizontal and vertical coverage area and thus curved approaches can be made if continuous distance of the aircraft is known. The aircraft range is provided by means of Precision DME discussed later in this chapter. Microwave Landing System uses a Time Referenced Scanning Beam (TRSB) to provide information for the aircraft on approach.

The glide slope is a fan-shaped vertical beam that scans up and down between 0.9 degrees and 20 degrees. The localiser is a fan-shaped azimuth beam that scans 40 degrees left and right of the runway to a distance of 20 nautical miles. Glide slope and localiser information is obtained as the aircraft receiver detects the localiser and glide slope beams passing in one direction and them again as the beams pass in the other direction and measures the time interval between the beam sweeps. The time intervals between the two beam sweeps of the localiser or azimuth beam is proportional to the angle between the aircraft and the runway centreline The time interval between the two beam sweeps of the glide slope or vertical beam is proportional to the angle of the aircraft above or below the selected glide slope.

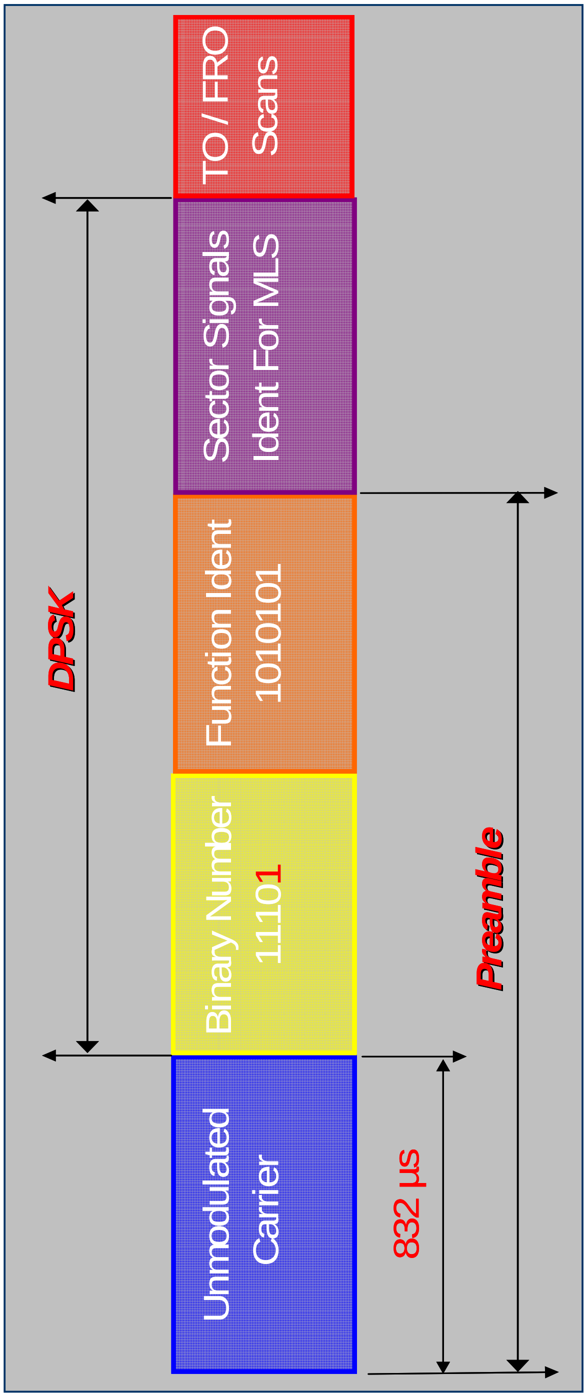
The Aircraft Equipment requires both the azimuth and vertical scanning beams to provide the pilots with aircraft position on the approach. The Microwave Landing System uses one frequency for both the azimuth and vertical beams and thus only the azimuth or the vertical beam can be transmitted at a time. It becomes important for the aircraft to be able to identify which beam is being transmitted and for the transmitter to provide a time reference for time interval between the two beam sweeps of the azimuth and elevation beams

The identification of the azimuth and vertical beam as well as the reference for the measurement of the time interval between the beam sweeps is achieved by means of the preamble portion of the digital information sent by the broad beam antenna of the transmitter. Azimuth and vertical beams are produced by Differential Phase Shift Keying (DPSK) at the beginning of each transmission. The pulses generated by the azimuth and elevation beams are measured at their 3dB down points, also known as half power points. This time measurement is done at the half power points as the pulses have a constant width of 100µ seconds, irrespective of the angle at which the aircraft approaches the MLS thus ensuring no time measurement error because of different pulse widths.

Format of the Digital Data

The information required for the aircraft equipment to provide the pilots with MLS information is transmitted in a digital format.

Format of the Digital Data



Format of the Digital Data

Unmodulated Carrier:

The Unmodulated Carrier is the Acquisition Signal and is used to stabilise the Phase Lock Loop system used to decode the DPSK. This data word is 832µ seconds wide.

Binary Number:

11101 is used as the Synchronization Code. The last " 1 " in the Binary Number is the Time Reference for elapsed time measurement.

Function Identification:

The Function Identification is a seven-bit data word identifying the transmission as either Azimuth (Horizontal) or Elevation (Vertical) beam.

Sector Signals:

Sector Signals are additional data signals including the MLS identification. The MLS identifies with the letter "M " for MLS and is followed by a three-letter code for the airfield.

TO / FRO Scans:

This data is used to indicate whether the Azimuth beam is scanning TO i.e. right to left as viewed from the aircraft or FRO i.e. left to right as viewed from the aircraft. This data will also indicate whether the Elevation beam is scanning TO i.e. from bottom 0.9 degrees to top 20 degrees or FRO from top 20 degrees to bottom 0.9 degrees.

Preamble:

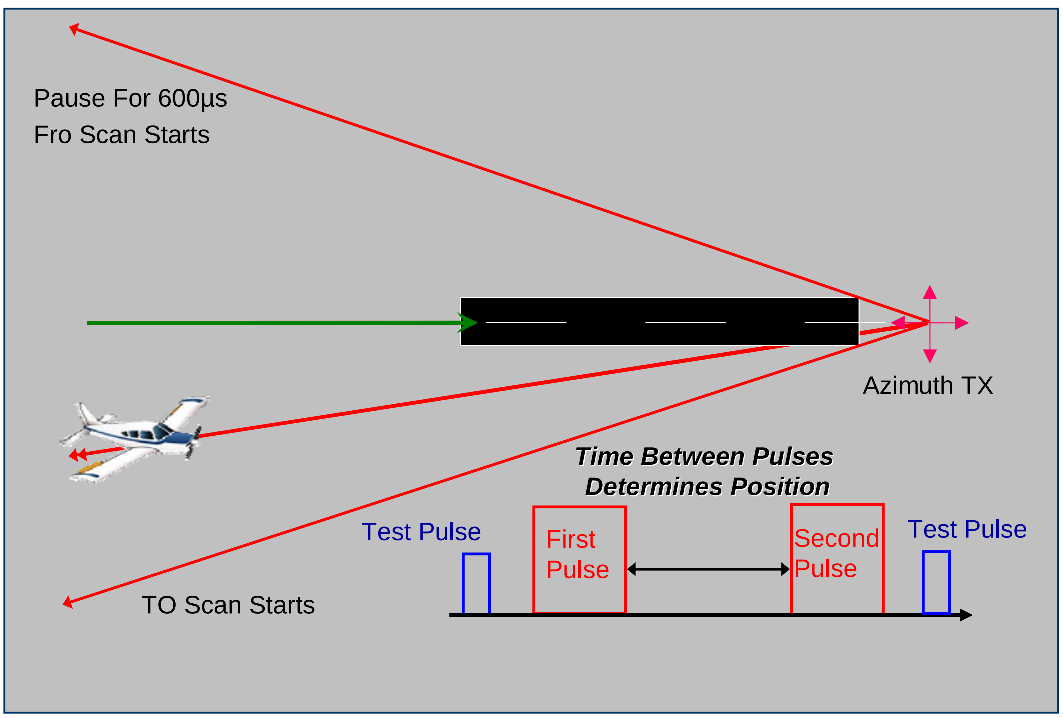
As can be seen from the illustration the Preamble includes the Unmodulated Carrier, the Binary Number and the Function Identification.

Differential Phase Shift Keying (DPSK):

As can be seen from the illustration the DPSK includes the Binary Number, the Function Identification and the Sector Signals.

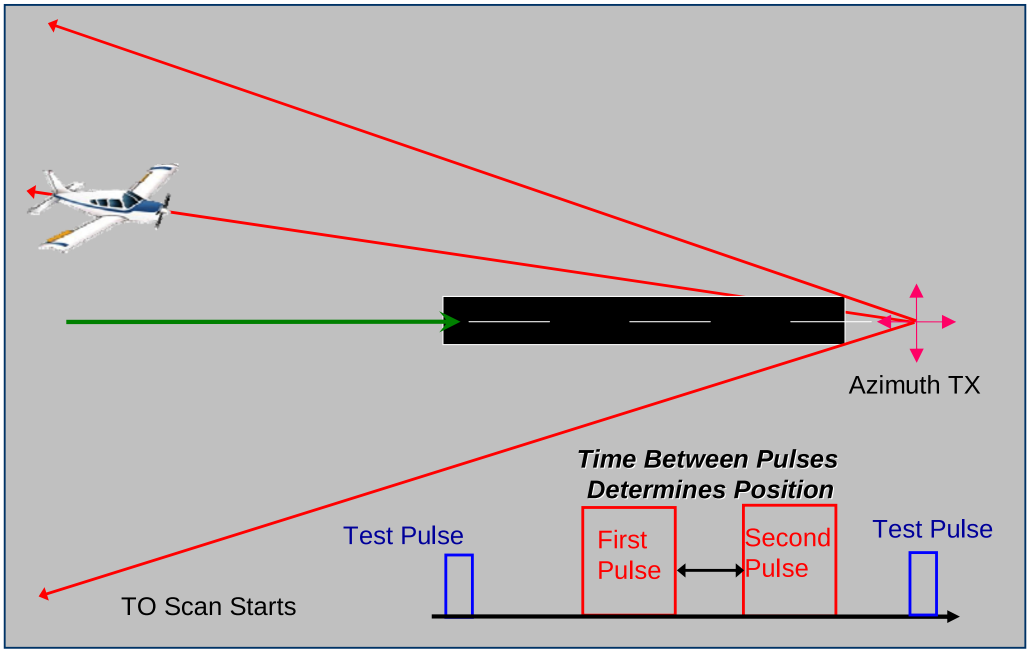
Transmission of the Azimuth (Horizontal) Beam

After the transmission of the Sector Signals two Test Pulses are transmitted. These test pulses are used to check the receiver accuracy. The time between the Test Pulses has a fixed value in the transmitter, if the sweep of the beam is not correct the time interval between the Test Pulses will be incorrect and the Transmitter will know that a fault exists in the system. After the TO Test Pulse is transmitted the TO scan begins with the beam 40 degrees to the right of the runway as viewed from the aircraft and stops 40 degrees to the left of the runway as viewed from the aircraft. The beam pauses for a period of 600µs before the FRO scan starts. The FRO scan moves the beam from 40 degrees left of the runway as viewed from the aircraft to 40 degrees right of the runway. The Azimuth beam is 2 degrees wide and the aircraft will receive two pulses, one as the beam moves from right to left and one as the beam
moves from left to right. The time interval between the two pulses is proportional to the aircraft position left or right of the runway centreline. The second test pulse or FRO test pulse is then transmitted to check that the beam sweep was correct. A long time interval between the two beam pulses indicates that the aircraft is to the right of the centreline and a short time interval between the two beam pulses indicates that the aircraft is to the left of the runway centreline.



Note a long time interval between the two beam pulses indicates the aircraft is to the right of the runway centreline

Transmission of the Azimuth (Horizontal) Beam



Note a short time interval between the two beam pulses indicates that the aircraft is to the left of the runway centreline

Transmission of the Elevation (Vertical) Beam

After the transmission of the Sector Signals two Test Pulses are transmitted. These test pulses are used to check the receiver accuracy. The time between the Test Pulses has a fixed value in the transmitter, if the sweep of the beam is not correct the time interval between the Test Pulses will be incorrect and the Transmitter will know that a fault exists in the system. After the TO Test Pulse is transmitted the TO scan begins with the beam 0.9 degrees above the runway as viewed from the aircraft and stops 20 degrees above the runway as viewed from the aircraft. The beam pauses for a period of 600µs before the FRO scan starts. The FRO scan moves the beam from 20 degrees above the runway as viewed from the aircraft to 0.9degrees above the runway. The Elevation beam is 2 degrees wide and the aircraft will receive two pulses, one as the beam moves from bottom to top and one as the beam moves from top to bottom. The time interval between the two pulses is proportional to the aircraft position above or below the selected glide slope. The second test pulse or FRO test pulse is then transmitted to check that the beam sweep was correct. A long time interval between the two beam pulses indicates that the aircraft is below the glide slope and a short time interval between the two beam pulses indicates that the aircraft is above the glide slope.

Microwave Landing System Indication

The Azimuth and Elevation data is supplied to an indicator, which displays the difference between actual aircraft Azimuth and Elevation positions to those Azimuth and Elevation values selected by the Microwave Landing System. The indications are similar to conventional ILS indications.

Precision Distance Measuring Equipment (DME / P)

Precision DME is used to provide the MLS equipment with accurate distance information of the aircraft from the station. When doing curved approaches the position of the aircraft in Azimuth, Elevation and Range from the station is continuously required. Precision Distance Measuring Equipment works on the same principal as Normal Distance Measuring Equipment. The main difference between the two systems is the shape of the pulse and the point where the pulse is measured. The Precision DME uses two modes of transmission during a MLS approach, these modes are:

- Initial Approach Mode (IAM) and is active from 22 nautical miles to 7 nautical miles.
- Final Approach Mode (FAM) and is active from 7 nautical miles to 0 nautical miles.

Initial Approach Mode (IAM) 22 NM to 7 NM:

- The aircraft interrogates the station in a 16 Hz rhythm with the pulse pair 12µs apart. The station will reply with the same pulse spacing.
- The DME/N pulse is 3.5µs wide.
- All the time measurements are taken at the 50% amplitude point of the pulses.
- This type of waveform is called a Gaussian Waveform or pulse.

Final Approach Mode (FAM) 7NM to 0 NM:

- At approximately 7 nautical miles range from the station the aircraft transmits FAM interrogation pulses in addition to IAM interrogation pulses.
- The Final Approach Mode (FAM) interrogation pulses are 18µs apart and are in a 40 Hz rhythm. The ground station detects these pulses and responds with the same pulse spacing.
- When the aircraft locks on to the ground station signals the IAM and FAM pulses stop alternating and the aircraft only transmits FAM pulses.
- This type of waveform is called a Cosine / Cosine Squared Waveform or pulse.
- The DME/P pulse is 3.5µs wide.
- All the time measurements are taken between 5% and 30% amplitude point of the pulses.

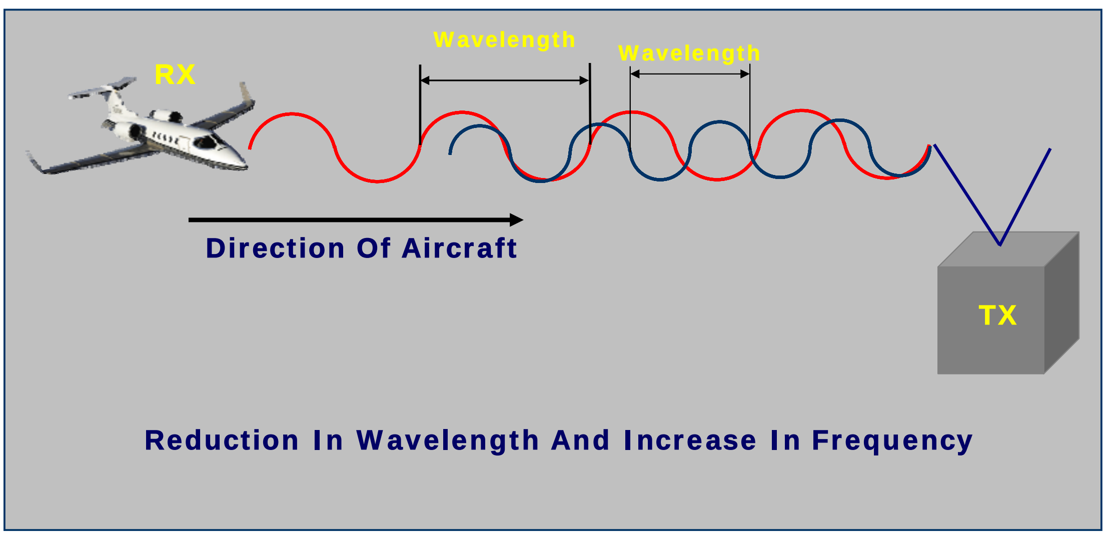
Chapter 20

DOPPLER RADAR

Doppler Radar is a self-contained navigational system providing the drift angle and spot groundspeed of an aircraft. Where there is a movement between a transmitter and a receiver a frequency shift will occur. The frequency shift of the radio wave is proportional to the relative movement of the receiver or the transmitter with respect to each other. This frequency shift is known as Doppler Shift, Doppler effect or Doppler Frequency and is abbreviated as (Fd). The frequencies used in the Doppler Radar are 8.8 GHz or 13.5 GHz, which provides a wavelength of 3.41 centimetres or 2.22 centimetres. This high frequency is used to ensure a narrow beam width and a narrow Doppler spectrum.

Principal of Operation

Doppler Radar works on the principal of relative movement between a transmitter and a receiver. When a receiver moves toward a transmitter or a transmitter moves toward a receiver the wavelength of the radio frequency is compressed causing the frequency of the radio wave to increase. This change in radio frequency is measured by the Doppler system and is known as Doppler Shift or (Fd). The faster the transmitter or receiver is moving the more the wavelength is compressed and the higher the frequency of the radio wave will be. The amount of Doppler Shift will be proportional to the aircraft ground speed.



Types of Doppler Radar Systems

There are three types of Doppler Radar systems we will look at in the Syllabus. They are:

- Receiver moving toward a transmitter. This is a theoretical system.
- Receiver and transmitter moving. This is an aircraft system.
- Receiver and transmitter moving with a depression angle. This is an aircraft system.

Receiver Moving Toward a Transmitter:

This is the basic principal of a Doppler Radar system. If a receiver is moving toward a transmitter then the relative movement causes a decrease in wavelength and an increase in frequency. The following formula is used to calculate the received frequency:

Frequency Shift :

Receiver Moving Toward A Stationary Transmitter

Reduction In Wavelength And Increase In Frequency

$$\text{Received Frequency (fR)} = f + \frac{Vf}{c}$$

Receiver and Transmitter Moving:

This is a basic aircraft system where the receiver and transmitter are in the aircraft and thus both moving at the same time and same speed in the same direction. The Doppler Shift will occur both when the radio wave is compressed going outbound and when returning to the aircraft. The effect on the compression is thus doubled.

Application To A Moving Aircraft :

Receiver And Transmitter Moving

Formula Only Applies If The Reflection Is Directly Ahead

$$\text{Received Frequency (fR)} = f + \frac{2Vf}{c}$$

Types of Doppler Radar Systems

Receiver and Transmitter Moving with a Depression Angle:

This is a basic aircraft system where the receiver and transmitter are in the aircraft and thus both moving at the same time and same speed in the same direction. The Doppler Shift will occur both when the radio wave is compressed going outbound and when returning to the aircraft. The effect on the compression is thus doubled. The radar beams are now directed toward the surface of the earth at an angle of between 60° and 70° from the aircraft's horizontal axis.

Depression Angle :

Receiver And Transmitter Moving And Signals Are Beamed Toward The Surface At An Angle From The Horizontal

Depression Angles Are Between 60° And 70° From The Horizontal

$$\text{Received Frequency (fR)} = f + \frac{2\,V\,f\ \cos Ø}{c}$$

Doppler Aerials

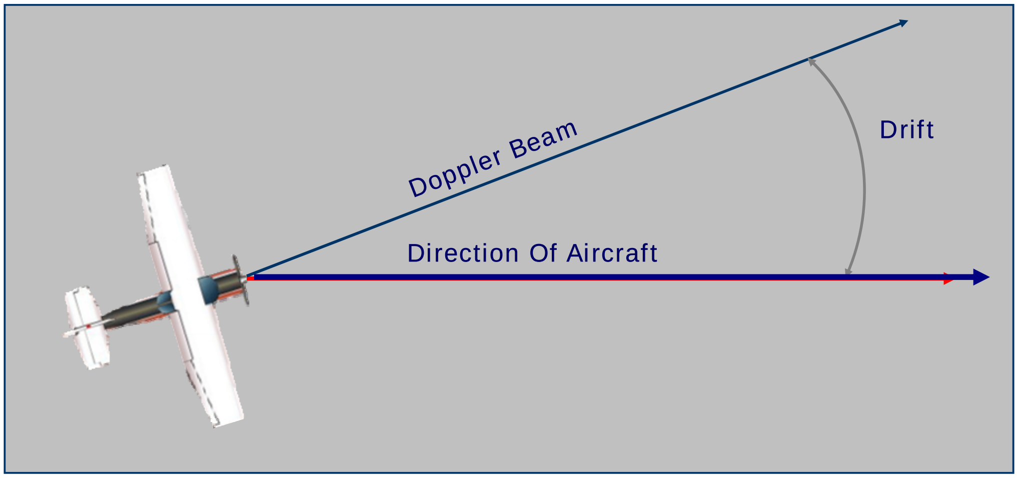
There are seven types of aerial configurations that are discussed in the radio syllabus. They are as follows:

- Single beam aerial system.
- Twin beam fixed aerial system.
- Twin beam rotating aerial system.
- Three beam rotating aerial system.
- Four beam fixed aerial system.
- Four beam rotating aerial system.
- Four beam Janus aerial system.

Doppler Aerials

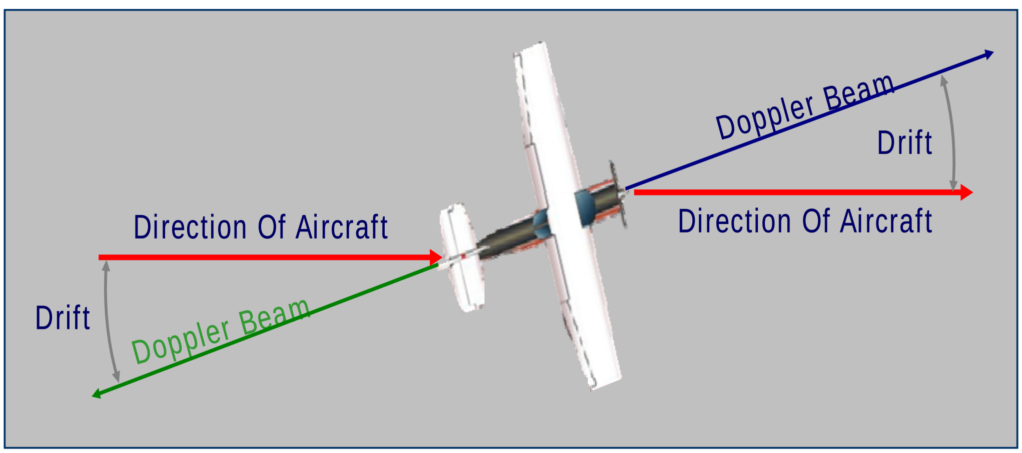
Single Beam Aerial System:

- The radio beam is transmitted ahead of the aircraft.
- The aerial is rotated until the received signal is maximum.
- The angle through which the beam is displaced is the drift.
- The Doppler Shift (Fd) is the direct measure of groundspeed.



Twin Beam Fixed Aerial System:

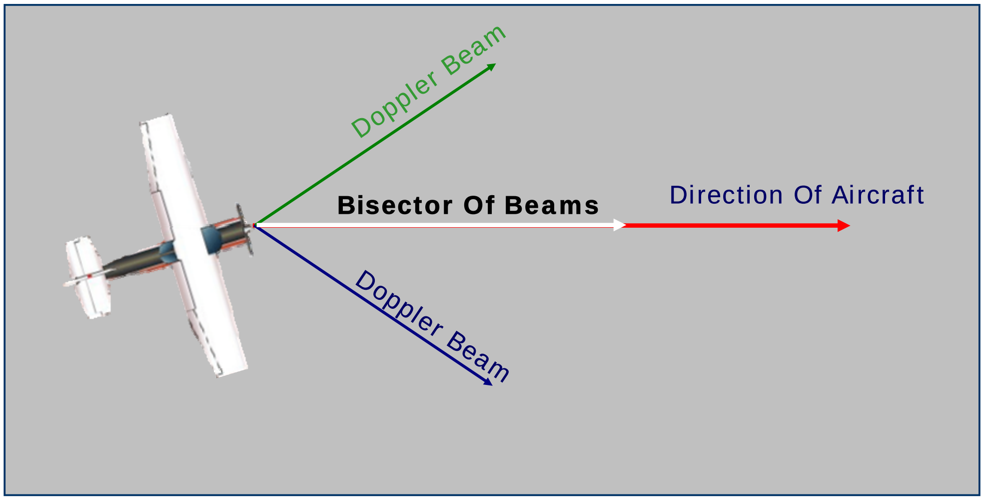
- One radio beam is transmitted ahead of the aircraft.
- One radio beam is transmitted aft of the aircraft.
- The two values of Doppler Shift (Fd) are compounded to give drift and groundspeed.



Doppler Aerials

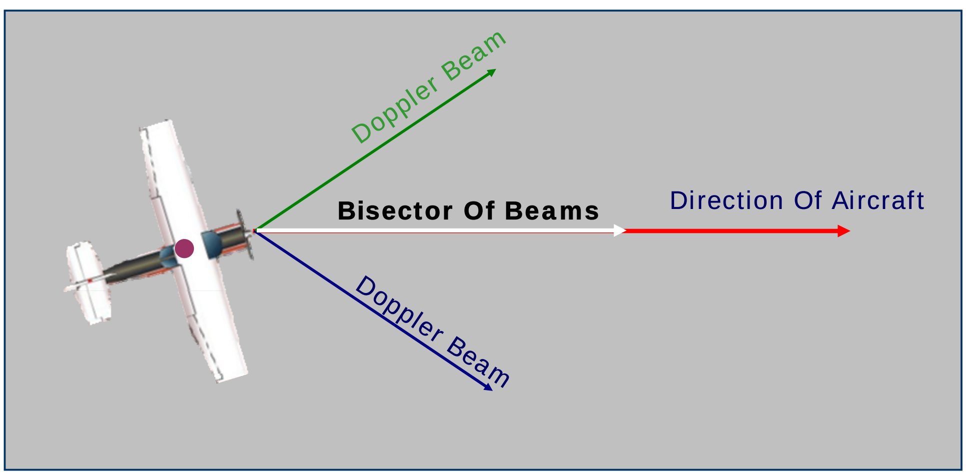
Twin Beam Rotating Arial System:

- Two radio beams are transmitted a fixed and known distance apart.
- The aerials are rotated about the fore / aft axis of the aircraft until the Doppler Frequency (Fd) received by the two beams is equal.
- The bisector of the angle between the two beams is equal to the track of the aircraft.



Three Beam Rotating Aerial System:

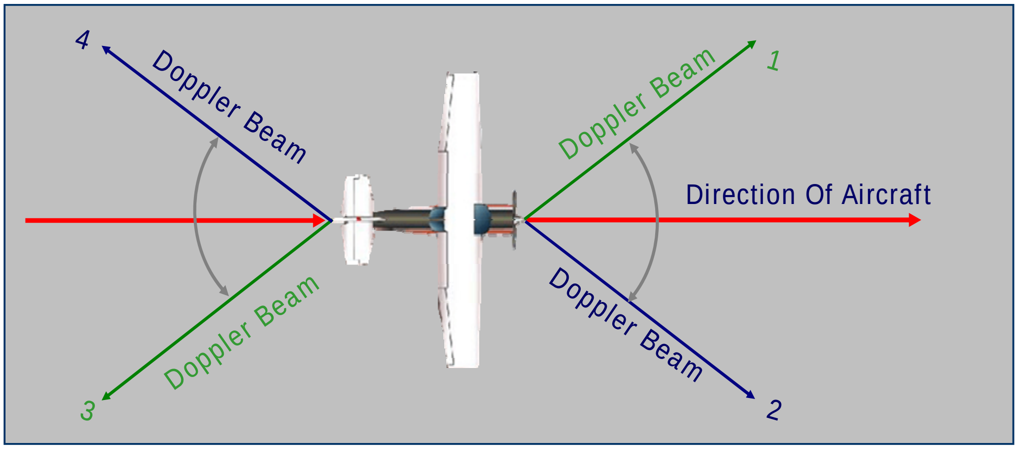
- Two radio beams are transmitted a fixed and known distance apart.
- The aerials are rotated about the fore / aft axis of the aircraft until the Doppler Frequency (Fd) received by the two beams is equal.
- The bisector of the angle between the two beams is equal to the track of the aircraft.
- The third radio beam is transmitter directly downward from the aircraft to calculate vertical velocity.



Doppler Aerials

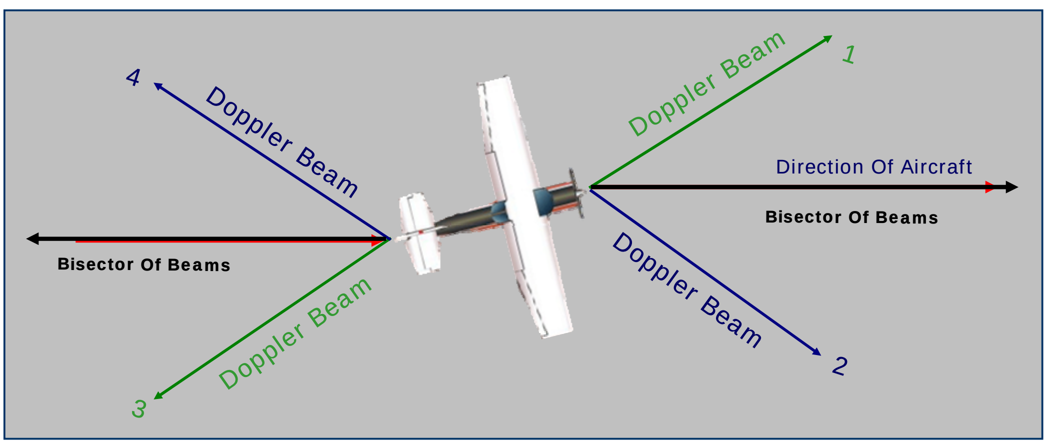
Four Beam Fixed Aerial System:

- Four beams are transmitted by two transmitters.
- The first transmitter transmits radio beams number one and three.
- The second transmitter transmits radio beams number two and four a half-second later.
- The four values of Doppler Shift are compounded to give drift and groundspeed.



Four Beam Rotating Aerial System :

- Four beams are transmitted by two transmitters.
- The first transmitter transmits radio beams number one and three.
- The second transmitter transmits radio beams number two and four a half-second later.
- The returning signals are mixed to produce a Doppler Beat Frequency.
- The difference between the nodes drives a motor which rotates the aerial to the aircraft track. When the aerial is in the correct position the nodes produce zero difference.
- Drift is measured by aerial displacement and groundspeed by a function of Doppler Shift or (Fd).



Doppler Aerials

Four Beam Janus Aerial System:

The four beam Janus aerial has a similar geometry to the four beam rotating aerials but has the following advantages:

- Radio beams are transmitted forward and aft simultaneously resulting in the correct extraction of the beat frequency.
- Pitch errors are reduced as the frequency from the front and back aerials are mixed and the errors are averaged out.
- The return radio beams are not affected by the roll of the aircraft.
- Conical beams are produced which improves the accuracy of the system.

Doppler Limitations and Errors

Flying Over Calm Sea:

The radio waves will not reflect back to the aircraft if the sea is calm as the depression angle of between 60 and 70 degrees will cause the radio wave to skip off the water away from the aircraft. There must be a wind of at least five knots to roughen the surface of the water and produce surfaces that will reflect the radio wave back to the aircraft.

Atmospheric Conditions:

Doppler radio waves will reflect off water drops due to their short wavelengths. If the aircraft flies through heavy rain the signals will not give the correct information back to the Doppler computer.

Low Flying:

The Doppler is a radar system that can not transmit and receive at the same time. If the aircraft is flying low the reflected radio signal is returned to the receiver while the Doppler transmitter is transmitting and is therefore ignored. No Doppler information is calculated.

Height Hole Effect:

This error is caused by the radar systems PRF. If the aircraft is higher than the maximum range of the Doppler, the retuning pulse from the ground will not arrive back at the aircraft before the next pulse is transmitted. This returning pulse will therefore be ignored. No Doppler information will be calculated.

Pitch and Roll:

The Doppler aerials are mounted on a gimbal system, which has a pitch limit of 20 degrees and a roll limit 0f 30 degrees.

Doppler Limitations and Errors

Aerial Misalignment:

This is a mechanical error in the alignment of the aerials with the fore / aft axis of the aircraft and will be present in all of the drift calculations from the Doppler computer.

Pitch Error:

This error occurs during a prolonged climb or descent when the aerials are not in the horizontal plane. This will result in a distance error in the Doppler computer calculation.

Sea Movement Error:

The Doppler calculates the drift angle of the aircraft by comparing the movement of the aircraft relative to the sea. It also assumes the aircraft is drifting not the sea moving sideways. If the sea moves with respect to the aircraft i.e. sea currents, a drift error of approximately 20% of the disturbing wind will be computed.

Sea Bias:

During the Doppler calculations different points are taken for measurement of the frequency shift as the beam strikes the water. These different measurements cause an error in groundspeed.

Latitude Error:

When the Doppler computer calculates groundspeed it uses the frequency shift of the radio wave or (Fd). This ground speed is then multiplied by time to give a distance, which is then converted into nautical miles using 6080 feet equals 1 nautical mile. The formula is only correct at the 48-degree north and south latitudes. If the Doppler is not at theses latitudes there will be an error in the distance calculation

Altitude Error:

The nautical mile is also represented on the surface of the earth, not at flight altitude. At an altitude of 40000 feet the Doppler computer will have an over-read error of approximately 2%.

Doppler Shift Calculations (Fd)

In these examples the Doppler Shift or (Fd) is required. It is of utmost importance to work in the correct mathematical units.

Example No 1:

A Receiver Flying Toward A Transmitter

An Aircraft Is Flying Toward A Transmitter At 480 KTS. If The Wavelength Of The Transmission Is 5 Cm What Is The Doppler Frequency Shift

$$fd = \frac{V}{\lambda}$$

480 KTS Is In **Nautical Miles Per Hour**. We Must Work In Meters And Seconds Therefore Convert : 480 KTS=**889 Km Per Hour** To Get To Meters 889x1000 = **889000 Meters Per Hour** To Get To Seconds / 60 For Minutes /60 For Seconds= **246.9 Meters Per Second**

$$fd = \frac{246.9 \text{ Meters Per Second}}{0.05 \text{ Meters}}$$

$$fd = 4938.889 \text{ HZ} \quad \text{Or} \quad 4.938 \text{ KHZ}$$

Doppler Shift Calculations (Fd)

Example No 2:

A Receiver Flying Toward A Transmitter

Determine The Doppler Frequency Shift In KHZ Of A Transmitter Moving Towards A Receiver At 360 Meters/Second And the Transmission Frequency Is 10 000 MHZ

$$fd = \frac{V}{\lambda} \qquad \lambda = \frac{C}{F}$$

$$\lambda = \frac{3 \times 10^{8} \text{ Meters Per Second}}{10000 \times 10^{6} \text{ Cycles Per Second}}$$

$$\lambda = 0.03 \text{ Meters}$$

A Receiver Flying Toward A Transmitter

Determine The Doppler Frequency Shift In KHZ Of A Transmitter Moving Towards A Receiver At 360 Meters/Second And The Transmission Frequency Is 10 000 MHZ

$$fd = \frac{V}{\lambda} \qquad \lambda = \frac{C}{F}$$

$$fd = \frac{360 \text{ Meters Per Second}}{0.03 \text{ Meters}}$$

$$fd = 12000 \text{ HZ} \quad \text{Or} \quad 12 \text{ KHZ}$$

Doppler Shift Calculations (Fd)

Example No 3:

A Doppler Transmitter/Receiver Flying With A Depression Angle

An Aircraft Doppler Transmits On A Frequency Of 13 500 MHZ At A Depression Angle Of 60° The Ground Speed Is 440 KTS What Is The Frequency Shift

$$\mathbf{fd} = \frac{2V \cos \varnothing}{\lambda} \qquad \lambda = \frac{C}{F}$$

$$\lambda = \frac{3 \times 10^{8} \text{ Meters Per Second}}{13500 \times 10^{6} \text{ Cycles Per Second}}$$

λ = 0.0222 Meters

A Doppler Transmitter/Receiver Flying With A Depression Angle

An Aircraft Doppler Transmits On A Frequency Of 13 500 MHZ At A Depression Angle Of 60° The Ground Speed Is 440 KTS What Is The Frequency Shift

$$\mathbf{fd} = \frac{2V \cos \varnothing}{\lambda}$$

440 KTS = 815KM
815 KM = 815000 M/Hr
815000 M/Hr \ 3600 = 226.4 m/S

$$\mathbf{fd} = \frac{2 \times 226.4 \text{ Meters Per Second } \times \cos 60}{0.0222 \text{ Meters}}$$

fd = 10192 HZ Or 10.192 KHZ

Doppler Shift Calculations (Fd)

Example No 4:

A Four Beam Janus System

An Aircraft Doppler Using A Four Beam Janus System Transmits On A Frequency Of 8700 MHZ. Depression Angle Is 60°. Azimuth Angle Is 60° Doppler Shift Is 12.5 KHZ What Is The Groundspeed Of The Aircraft

$$fd = \frac{4V \text{ Cos Ø Cos Ø}}{\lambda} \qquad \lambda = \frac{C}{F}$$

$$\lambda = \frac{3 \times 10^8 \text{ Meters Per Second}}{8700 \times 10^6 \text{ Cycles Per Second}}$$

$$\lambda = 0.0345 \text{ Meters}$$

A Four Beam Janus System

An Aircraft Doppler Using A Four Beam Janus System Transmits On A Frequency Of 8700 MHZ. Depression Angle Is 60°. Azimuth Angle Is 60° Doppler Shift Is 12.5 KHZ What Is The Groundspeed Of The Aircraft

$$fd = \frac{4V \text{ Cos Ø Cos Ø}}{\lambda} \qquad \lambda = \frac{C}{F}$$

$$12.5 \times 10^3 \text{ HZ} = \frac{4 \times V \text{ Meters Per Second} \times \text{Cos } 60 \times \text{Cos } 30}{0.0345 \text{ Meters}}$$

$4 \times V$ = 995.958 Meters Per Second

V = 248.9 Meters Per Second

V = 896 Km Per Hour Or 484 KTS

ANNEXURE A

TYPICAL EXAMINATIONS

Mock Examination 1

1. When using HF for communications over a specified distance, transmissions at night should be done on frequencies almost half of the optimum day frequency because:

   (a) The ionosphere is lower at night requiring a higher critical angle which occurs at a lower frequency;
   (b) At night the reflection height increase and layer density decreases, using lower frequencies reduces the skip distance;
   (c) A lower frequency reduces the attenuation allowing the ground wave to have a greater range, so reducing the dead space.

2. The magnetic component of a radio wave emitted from a vertical aerial, travels in the:

   (a) Vertical plane;
   (b) The horizontal plane;
   (c) Vertical plane with the electrical component but ninety degrees out of phase.

3. Super High Frequency (SHF) is utilised for:

   (a) RADAR;
   (b) Communication;
   (c) ILS.

4. If wavelength is 3 cm, the frequency is:

   (a) 74 MHz;
   (b) 100 GHz;
   (c) 10 000 MHz.

5. The E layer in the ionosphere is also known as the:

   (a) Appleton layer;
   (b) Kennely-Heavyside layer;
   (d) Barret layer.

6. The following emergency frequencies are available for the use of aircraft in distress:

   (a) 8 364 KHz 500 MHZ 121,5 MHz and 243 MHz;
   (b) 8 364 KHz 500 KHZ 121,5 MHz and 243 MHz;
   (c) 8 364 MHz 500 MHZ 121,5 MHz and 243 MHz.

7. The following relative bearings are obtained from an NDB. Rel. Bearings No. 1: 075°. Rel. Bearing No. 2: 090°. The time between bearings is 7,75 minutes, and the G/S is 130 KTS. The time and distance to the beacon is:

   (a) 31 MIN 67 NM;
   (b) 25 MIN 54 NM;
   (c) 20 MIN 43 NM.

8. An ICOA NDB frequency band is:

   (a) 200 KHz – 455 KHz;
   (b) 200 KHz – 800 MHz;
   (c) 200 KHz – 1750 KHz.

9. The frequency band most affected by static, is:

   (a) VHF;
   (b) VLF;
   (c) UHF.

10. The wavelength of a radio wave transmission is:

   (a) The number of cycles in one second;
   (b) The distance travelled during the transmission of one cycle;
   (c) The complete change of direction current.

11. The Radio Magnetic Indicator (RMI) indicates:

   (a) Compass heading;
   (b) Magnetic heading;
   (c) True heading.

12. Fading of low frequency and medium frequency at night may be due to:

   (a) Poor receiver sensitivity and ionospheric attenuation;
   (b) Simultaneous reception of sky and surface waves;
   (c) Reception of space waves and atmospheric attenuation.

13. When flying towards an NDB with a 000° relative bearing in a left crosswind, the result is:

   (a) The ground track curves to the downwind side of the NDB;
   (b) The ground track curves to the upwind side of the NDB;
   (c) The aircraft makes a slow but continuous turn to the right.

14. The frequency of 10,2 KHz has a wavelength of:

   (a) 15.88 nm;
   (b) 16.12 nm;
   (c) 17.05 nm.

15. The frequency band of VOR equipment is from:

   (a) 112 to 117,95 MHz;
   (b) 108 to 117,95 MHz;
   (c) 109 to 121 MHz.

16. The locator NDB type of emission recommended by ICAO is A2A because:

    (a) The signal is more stable than A1A;
    (b) The signal is less affected by night effect;
    (c) The ADF needle does not wander during transmission of the indent.

17. When the aircraft heading agrees approximately with the Omni-bearing selector setting on a VOR indicator:

    (a) Fly toward the deviation needle provided FROM is indicated;
    (b) Fly toward the deviation needle regardless of the TO-FROM indication;
    (c) Fly away from the needle provided FROM is indicated.

18. The VOR selector in an aircraft, heading 150 (M), is tuned to a facility. With 170 on the OBS and TO indicated, the left/right needle is displaced very close to the maximum deflection right, indicating that the aircraft's magnetic orientation is approximately:

    (a) South of the station;
    (b) On radial 340 from the facility;
    (c) North of the VOR.

19. The reference signal of a VOR has a sub-carrier wave. The purpose of the sub-carrier wave modulation is to:

    (a) Provide for a facility identification;
    (b) Provide datum to determine phase difference;
    (c) Modulate the directional signal.

20. An aircraft is maintaining the 140 radial inbound to a VOR station with a drift of 8 degrees port. Variation at the aircraft's position 18 W. The aircraft's magnetic heading is:

    (a) 330 (M);
    (b) 328 (M);
    (c) 314 (M).

21. The characteristics of the reference signal of a VOR transmitter are:

    (a) Amplitude modulated at 30 Hz and rotating figure of eight radiation;
    (b) Frequency modulation at 30 Hz and an omni-directional radiation;
    (c) Frequency modulated at 150 Hz and a conical radiation.

22. Two VOR's, both at 200 feet and 161 NM apart, are positioned on the centre line of an airway. The minimum altitude at maximum range guarantees positive reception form both VOR's simultaneously is:

    (a) 5 052 feet;
    (b) 2 526 feet;
    (c) 3 157 feet.

23. An aircraft is on a heading of 280 (M) and on a bearing of 090 (M) from the VOR. The bearing that should be selected on the omni-bearing selector in order to centralise the VOR/ILS left/right deviation needle with TO on the TO/FROM indicator, is:

    (a) 280;
    (b) 270;
    (c) 090.

24. Aircraft heading 315°, ADF RMI reading 090°. The quadrantal error of this bearing is:

    (a) Maximum;
    (b) Zero;
    (c) Proportional to sine heading times the signal strength.

25. An aircraft is maintaining track outbound from the NDB with a constant relative bearing of 184°.

    To return to the NDB the relative bearing to maintain is:

    (a) 356°;
    (b) 000°;
    (c) 004°.

26. At 1000 Z an aircraft is overhead NDB PE en-route to NDB CN.
    Track 075° (M), heading 082° (M).

    At 1029 Z NDB PE bears 176° Relative and NDB CN bears 352° Relative.

    The heading to steer at 1029 Z to reach NDB CN is:

    (a) 078° (M);
    (b) 079° (M);
    (c) 081° (M).

27. The VOR monitor will warn the control point and possibly switch off the station radiation with an occurrence of:

    (a) A change in bearing information in excess of 10 degrees;
    (b) A reduction of 15 percent in bearing information;
    (c) A change in bearing information in excess of 1 degrees.

28. ILS transmission identification takes place on:

    (a) Glide path;
    (b) Localiser;
    (c) Both the glide path and the localiser.

29. The approximate height of an aeroplane maintaining a 3 degree glideslope when over the outer marker sited 4,3 NM from the landing threshold, calculated by using the 1:60 rule is:

    (a) 1 370 feet;
    (b) 1 307,2 feet;
    (c) 3 186,4 feet.

30. An ILS category 1 localiser coverage extends from the transmitter at 10° either side of the centre line to a distance of:

    (a) 25 NM;
    (b) 35 NM;
    (c) 45 NM.

31. With reference to Airborne Weather Radar, the object of the iso-echo contour system is to:

    (a) Progressively reduce the radar gain as the aircraft approaches a cloud;
    (b) Indicate the areas in which cloud penetration is advisable;
    (c) Indicate the areas in a cloud where severe turbulence is present.

32. For good target resolution the Weather radar beam width must be kept as:

    (a) Constant as possible;
    (b) Wide as possible;
    (c) Narrow as possible.

33. An aircraft receives a reply from a DME (fixed delay 50 us) 995 us after transmission of the interrogation pulse. The slant range of the aircraft is:

    (a) 76.54 nm;
    (b) 82.59 nm;
    (c) 88.34 nm.

34. If single coded identification is received only once every thirty seconds from a VOR/DME station, it means:

    (a) VOR/DME components are both operative but voice identification is inoperative;
    (b) The DME component is operative;
    (c) The VOR component is operative.

35. VOR ‘B’ is situated at a distance of 120 NM from VOR ‘A’ on radial 233. An aircraft at G/S 300 knots, is approaching VOR ’A’ on a track of 323 (M) in zero wind, and the VOR at B indicates 278 on the aircraft’s RMI. Assuming variation is constant, the time to reach B will be:

    (a) 24 minutes;
    (b) 34 minutes;
    (c) 40 minutes.

36. An aircraft heading 040° (M) has an ADF reading of 060° Relative.
The alteration of heading to intercept the 120° track inbound to the NDB at 50° in zero wind conditions is:

(a) 30° Right;
(b) 40° Right;
(c) 50° Right.

37. An aircraft heading 135° (M) with 5° Right drift intercepts the 082° (M) track outbound from the NDB. The relative bearing of the ND that confirms track interception is:

(a) 122° Relative;
(b) 127° Relative;
(c) 132° Relative.

38. In Airborne Search Radar (ASR), resolution and distortion of clouds and ground features is related to beam width and pulse length for the following reasons:

(a) As the beams widen with range a single object appears to be double its size at twice the range;
(b) An object reflects an echo for the time duration of the pulse and is presented on a screen measuring range, the time base of which is halved and so is the size of the image;
(c) On the time base, the pulse extends the PPI image by a distance equivalent to one half of the pulse length.

39. Two advantages of single side band transmissions are:

(a) Broader bandwidth and transmitting power concentrated in two frequencies instead of three;
(b) Narrow bandwidth and transmitting power concentrated in one or two frequencies instead of three;
(c) Narrow bandwidth and transmitting power concentrated in three frequencies instead of two.

40. If a VOR transmitter's elevation is 100 FT and an aircraft's altitude is 12 500 FT, the maximum range that the aircraft can receive the VOR signals is:

(a) 152 NM;
(b) 170 NM;
(c) 185 NM.

41. At a given position the variable phase of a VOR transmission lags the reference phase by 60 degrees, making the bearing to the facility:

(a) 060 degrees;
(b) 240 degrees;
(c) 300 degrees.

42. A VOR frequency is selected and VOR and DME indications are received on the appropriate indicators. The VOR indent is GDV and the DME MFT.

    (a) Co-located, and the bearing and range can be plotted from the VOR position;
    (b) Serving the same location, and may be plotted after checking the two positions;
    (c) At two independent positions and are not related.

43. When using Airborne Search (ASR), the distortion of shapes and sizes portrayed on the radar screen is due to:

    (a) The use of the cosecant beam for mapping;
    (b) The radial beam being portrayed on a linear screen;
    (c) The beam adding one half of the beam width distance on either side of the portrayed object.

44. An airborne SSR transponder recognises an invalid interrogation by a side lobe of the main beam transmission by comparing the:

    (a) Time intervals between the P1, P2 and P3 pulses;
    (b) Time intervals between the P1 and P3 pulses;
    (c) Relative amplitude of the P1, P2 and P3 pulses.

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    (b) Time intervals between the P1 and P3 pulses;
    (c) Relative amplitude of the P1, P2 and P3 pulses.

46. An aircraft heading 045° (M), is on a true bearing of 135° from a VOR. Variation 8°E. If the OBS is set at 315 the indication on a 5 dot CDI would be:

    (a) TO 4 dots left of centre;
    (b) TO needle central;
    (c) TO 4 dots right of centre.

Mock Examination 2

1. Basic radar operates on:

    (a) HF and lower frequencies only;
    (b) VHF and higher frequencies;
    (c) Any frequency in the RF band.

2. If a radio wave is horizontally polarised the:

    (a) Electrical component is in the vertical plane and the magnetic component is horizontal;
    (b) Electrical component is in the horizontal plane and the magnetic component is vertical;
    (c) Magnetic component is horizontal with the electrical component 180° out of phase.

3. The principal factors affecting the accuracy of VOR radials as indicated by the aircraft's equipment are:

    (a) Aircraft equipment error, site error, refraction error and propagation error;
    (b) Propagation error, site error, aircraft equipment error and night effect;
    (c) Site error, interference error, propagation error and aircraft equipment error.

4. Airborne Search Radar (ASR) is a:

    (a) Primary radar;
    (b) Secondary radar;
    (c) SSR.

5. The accuracy of VOR is better than:

    (a) ± 1°;
    (b) ± 4°;
    (c) ± 6°.

6. The principle of VOR is bearing measurement by:

    (a) Wave transmissions;
    (b) Phase comparisons;
    (c) Limacon positions.

7. The type of emission used for ILS localiser and glidepath transmissions is:

    (a) A1A;
    (b) A2A;
    (c) A3E.

8. An aircraft heading 065° (M) has the VOR CDI OBS set a t 095. The left/right needle of a 5 dot CDI is 3 dots left of centre with TO indicated. The aircraft is on a radial:

   (a) 101°;
   (b) 269;
   (c) 281.

9. The frequency band normally associated with an ILS localiser is:

   (a) 108,0 – 119,0 MHz;
   (b) 118,0 – 135,975 MHz;
   (c) 108,1 – 111,95 MHz.

10. The reference signal of a VOR has a sub-carrier wave. The purpose of the sub-carrier wave modulation is:

    (a) Provide for facility identification;
    (b) Provide a datum to determine phase difference;
    (c) Modulate directional signal.

11. When the main VOR transmitter is switched off and a standby transmitter comes into operation, bearing information may be unreliable and as a warning:

    (a) No identification signal is transmitted;
    (b) Identification signals are transmitted together with voice transmission warnings;
    (c) A continuous bleep is transmitted.

12. An aircraft's heading is 070° (M) Variation 10°E. An NDB bears 200 relative. The RMI will indicate:

    (a) 260;
    (b) 280;
    (c) 270.

13. The ILS localiser is calibrated for accuracy up to and inclusive of a distance of:

    (a) 25 NM;
    (b) 18 NM;
    (c) 35 NM.

14. The normal glidepath angle of an ILS is:

    (a) 5°;
    (b) 3°;
    (c) 4°.

15. An aircraft flying a constant heading with 8° left drift and is making good a track parallel to the centre line of an airway, but 15 NM off to the left of the centre line. The ADF reading while 90 NM short of a NDB on the airway, is:

    (a) 002;
    (b) 010;
    (c) 358.

16. Radio Magnetic Indicators (RMI) combine and indicate information from separate sources on one dial, namely:

    (a) Only bearings from VOR and NDB facilities;
    (b) The aircraft heading from a remote-reading compass, bearings from VOR facilities and bearings from NDB facilities;
    (c) The true heading from remote-reading compass, bearings from a VOR facility and a bearing from an NDB facility.

17. While on a heading of 210° (M) and turned to a VOR, with 235 on the OBS, the TO/FROM indicator reads TO and the left/right needle is displaced close to the maximum left deflection position. The approximate position of the aircraft in relation to the VOR is on radial:

    (a) 045;
    (b) 235;
    (c) 055.

18. A VOR and a NDB are co-located on an aerodrome where the variation is 17°W. An aircraft is flying where the variation is 19°W on a true bearing of 315° from the aerodrome. The VOR and ADF readings on a twin pointer RMI would be:

    (a) VOR 152° ADF 154°;
    (b) VOR 152° ADF 152°;
    (c) VOR 154° ADF 152°.

19. The distance from a VORTAC according to an Omega reading is 16 NM. The aircraft is at a height of 18 228 feet. The DME indication is:

    (a) 15,72 NM
    (b) 16,36 NM;
    (c) 16,28 NM.

20. Outbound from Upington on track for VWV with 7 degrees right drift. In order to maintain the required QDR the ADF, which is tuned to UP, will indicate:

    (a) 187;
    (b) 180;
    (c) 173.

21. The glide path angle for an ILS is 2,7 degrees. The aeroplane's ground speed is 115 KTS, IAS 110 KTS and the TAS is 120 KTS. Using the 1:60 rule the rate of decent of the ILS is:

    (a) 517 FT/MIN;
    (b) 495 FT/MIN;
    (c) 540 FT/MIN.

22. A DME transponder with a fixed delay of 50 micro-seconds, receives an interrogating signal from an aircraft 285 micro-seconds after transmission, making the slant range to the aircraft read:

    (a) 23 NM;
    (b) 46 NM;
    (c) 42 NM.

23. ILS marker indications are:

    (a) Amber light coding alternate dots and dashes;
    (b) White light coding six dots per second;
    (c) Blue light coding two dashes per second.

24. The maximum safe deviation from the ILS path during approach using a 5 dot CDI is:

    (a) 2 dots fly up;
    (b) 2½ dots fly up;
    (c) 3 dots fly up.

25. The DME automatic standby will activate the DME interrogator when:

    (a) Random filler pulse from the transponder are received;
    (b) A VOR frequency that has a frequency paired DME is selected;
    (c) The DME indent signal is received.

26. A bearing accuracy of ± 3,5 degrees is guaranteed from each of two VOR's sited on the centre line of an airway 10 NM wide. In order to ensure that aircraft correctly using these facilities remain within airway at midpoint, the facilities may not be further apart than:

    (a) 84 NM;
    (b) 168 NM;
    (c) 210 NM.

27. Between Upington and Victoria West the aircraft is on radial 252 KMV where variation is 20 W. At the aircraft variation is 21 W. From the aircraft's position the heading to steer towards KMV (zero wind) is:

    (a) 072 (T);
    (b) 052 (T);
    (c) 051 (T).

28. A particular VOR station is undergoing routine maintenance. This is confirmed by:

    (a) Transmitting a series of dots after each identification signal;
    (b) The removal of the navigational feature;
    (c) The removal of the identification signal.

29. On a VOR the full deflection of the deviation needle left or right represents a departure from the selected radial of:

    (a) 5 degrees;
    (b) 10 degrees;
    (c) 2,5 degrees.

30. In order for a GPS receiver to conduct a RAIM it must use a minimum of:

    (a) Three satellites plus a barometric input;
    (b) Four satellites;
    (c) Five satellites.

31. A VOR frequency is selected and VOR and DME indications are received on the appropriate indicators. The VOR indent is CPL and the DME is CPZ. This indicates that VOR and ME transmitters are:

    (a) Co-located, and the bearing and range van be plotted from the VOR position;
    (b) Serving the same location and may be plotted after checking the two positions;
    (c) At two independent positions and are not related.

32. If a signal of two hertz was transmitted for one second, the physical space occupied by the signal would be:

    (a) 300 000 000 Metres;
    (b) 150 000 000 Metres;
    (c) 600 000 000 Metres.

33. When using a VOR facility with 050 set on the OBS, the CDI needle is central, but the TO/FROM indication is inoperative. If the OBS is now set to 060 and the needle is deflected to the right, the aircraft is on the:

    (a) 050 radial;
    (b) 230 radial;
    (c) Either the 050 or 230 radial.

34. Two radio aids to navigation that may share a common receiving aerial, are:

    (a) VOR and ADF;
    (b) ADF and Loran C;
    (c) ILS and ADF.

35. Full scale deviation of RNAV CDI in the approach mode is:

    (a) 1,25 NM;
    (b) 2,50 NM;
    (c) 5,00 NM.

36. When using RNAV in the approach mode, the distance between the parent VOR/DME and the final approach waypoint should not be greater than:

    (a) 10 NM;
    (b) 25 NM;
    (c) 50 NM.

37. The maximum range of search radar is dependant on the:

    (a) Radio frequency;
    (b) Pulse recurrence frequency;
    (c) Pulse width.

38. The minimum range of search radar is dependant on the:

    (a) Radio frequency;
    (b) Pulse recurrence frequency;
    (c) Pulse width.

39. The use of weather radar (ASR) when the aeroplane is on the ground is:

    (a) Prohibited;
    (b) Permitted but used with extreme caution;
    (c) Permitted in maintenance area only.

40. The brilliance of a Cathode Ray Tube (CRT) display is controlled by the:

    (a) 1st and 3rd anodes;
    (b) 2nd anode;
    (c) Grid.

41. On a Cathode Ray Tube using a horizontal time base, unwanted echoes or “grass” can be reduced or removed from the screen by the:

    (a) Graphite coating;
    (b) X plates;
    (c) Gain control.

42. An X channel DME transponder will not reply to a Y channel interrogation on the same frequency because the:

    (a) Spacing between the interrogation pulses is different;
    (b) Interrogation and reply frequencies are 63 MHz apart;
    (c) Random PRF, which is unique to each aircraft.

43. The frequency band in which Secondary Surveillance Radar (SSR) operates is:

    (a) VHF;
    (b) UHF;
    (c) SHF.

44. A carrier wave with amplitude of 5V is modulated by an audio frequency with amplitude of 3 V. The depth of modulation is:

    (a) 40 %;
    (b) 60 %;
    (c) 167 %.

45. To double the range of an NDB the transmission power must be increased by a factor of:

    (a) 2;
    (b) 4;
    (c) 8.

46. Selecting a lower HF/RT frequency results in:

    (a) An increase of the critical angle;
    (b) An increase of the dead space;
    (c) A decrease of the skip distance.

47. Static interference increases with an:

    (a) Increase in frequency;
    (b) Decrease in frequency;
    (c) Decrease in wavelength.

48. The bending of a radio wave by the Earth's surface is greatest on:

    (a) VLF;
    (b) LF;
    (c) MF.

49. With frequency modulated transmissions the:

    (a) Amplitude is constant and the frequency varies;
    (b) Frequency is constant and the amplitude varies;
    (c) Amplitude and frequency vary.

50. With frequency modulated transmissions the:

    (a) Amplitude is constant and the frequency varies;
    (b) Frequency is constant and the amplitude varies;
    (c) Amplitude and frequency vary.

51. An aircraft's DME receiver will not accept replies to its own interrogations that are reflected from the ground or clouds, because of the:

    (a) Random PRF which is unique to each aircraft;
    (b) Interrogation and reply frequencies being 63 MHz apart;
    (c) Interrogation pulses being transmitted in pairs.

52. An aircraft climbing through 6500 feet:

    Altitude director 4° pitch up, weather radar stabiliser off
    Cloud range 27 nautical miles, tilt control 3° up
    Beam width 5°

    The height of the top of the cloud is:

    (a) 15 000 ft;
    (b) 17 000 ft;
    (c) 19 000 ft.

53. Side lobe suppression in SSR is accomplished by:

    (a) Defruiting which removes unwanted replies from aircraft by the use of killer circuits;
    (b) Aircraft close to the transmitter selecting LO sense on the receiver;
    (c) Transmission of a third omni-directional pulse weaker than the main pulses but stronger than the side lobe pulses.

MOCK EXAMINATION 3

1. The airborne equipment of an ILS consists of:

   (a) HF localizer receiver, VHF glide path receiver, 75 MHz marker beacon receiver;
   (b) UHF localizer receiver, VHF glide path receiver, VOR/ILS indicator;
   (c) VHF localizer receiver, UHF glide path receiver, ILS indicator.

2. The factors affecting the accuracy of a VOR reading are:

   (a) Airborne equipment;
   Site error;
   Propagation error;
   Refraction error;
   (b) Airborne equipment;
   Site error;
   Conduction error;
   Propagation error;
   (c) Airborne equipment;
   Site error;
   Propagation error;
   Interference error.

3. Airborne Search Radar (ASR) is a:

   (a) Primary radar;
   (b) Secondary radar;
   (c) SSR.

4. The theoretical maximum range of a VOR in NM is:

   (a) 1,25 times the square root of the transmitter height plus
   1,25 times the square root of the receiver height;
   (b) 1,5 times the square root of the transmitter height plus
   1,5 times the square root of the receiver height;
   (c) 1,15 times the square root of the receiver height plus
   1,15 times the square root of the transmitter height.

5. In respect of the use of GPS P DOP is a loss of:

   (a) Ionosphere effects;
   (b) Relative position of the visible satellites;
   (c) Multi-path signals from some satellites;
   (d) Use of satellites at low altitudes.

6. The principal of VOR is bearing measurement by:

   (a) Wave transmission;
   (b) Phase comparison;
   (c) Limacon positions.

7. A VOR cardioid is also called a:

   (a) Limacon;
   (b) Rotating signal;
   (c) Result of the loop aerial.

8. The frequency band normally associated with an ILS localiser is:

   (a) 108,0 – 119,0 MHz;
   (b) 118,0 – 135,975 MHz;
   (c) 108,1 – 111,95 MHz.

9. The reference signal of a VOR has a sub-carrier wave. The purpose of the sub-carrier wave modulation is to:

   (a) Provide for facility identification;
   (b) Provide a datum to determine phase difference;
   (c) Modulate the directional signal.

10. When the main VOR transmitter is switched off and a standby transmitter comes into operation, bearing information may be unreliable and as a warning:

   (a) No identification signal is transmitted;
   (b) Identification signals are transmitted together with voice transmission warnings;
   (c) A continuous bleep is transmitted.

11. An aircraft's heading is 070° (M) Variation 10°E. An NDB bears 200 relative. The RMI will indicate:

   (a) 260;
   (b) 280;
   (c) 270.

12. The ILS localiser is calibrated for accuracy up to and inclusive of a distance of:

   (a) 25 NM;
   (b) 18 NM;
   (c) 35 NM.

13. The normal glidepath angle of an ILS is:

    (a) 5°;
    (b) 3°;
    (c) 4°.

14. An aircraft flying a constant heading with 8° left drift and is making good a track parallel to the centre line of an airway, but 15 NM off to the left of the centre line. The ADF reading while 90 NM short of a NDB on the airway, is:

    (a) 002;
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15. Radio Magnetic Indicators (RMI) combine and indicate information from separate sources on one dial, namely:

    (a) Only bearings from VOR and NDB facilities;
    (b) The aircraft heading from a remote-reading compass, bearings from VOR facilities and bearings from NDB facilities;
    (c) The true heading from remote-reading compass, bearings from a VOR facility and a bearing from an NDB facility.

16. While on a heading of 210° (M) and turned to a VOR, with 235 on the OBS, the TO/FROM indicator reads TO and the left/right needle is displaced close to the maximum left deflection position. The approximate position of the aircraft in relation to the VOR is on radial:

    (a) 045;
    (b) 235;
    (c) 055.

17. The term “Mode” when used in conjunction with ATC Surveillance Radar refers to:

    (a) An omni-directional framed pulse interrogation at 1 030 MHz, having the ability to trigger a reply from all aircraft within range;
    (b) Interrogation by a train of 12 pulses, spaced from 8-21 micro-seconds apart at 1 030 MHz in order to trigger a reply at 1 0090 MHz from aircraft with the code selected;
    (c) A directional pulsed interrogation at 1 030 MHz having a distinct characteristic of framed pulses, the purpose of which is to generate a reply from an airborne unit.

18. Outbound from Upington on track for VWV with 7-degree right drift. In order to maintain the required QDR the ADF, which is turned to UP, will indicate:

    (a) 187;
    (b) 180;
    (c) 173.

19. The glidepath angle for an ILS is 2,7 degrees. The aeroplane's groundspeed is 115 KTS, IAS 110 KTS and the TAS is 120 KTS. Using the 1:60 rule the rate of decent of the ILS is:

(a) 517 FT/MIN;
(b) 495 FT/MIN;
(c) 540 FT/MIN.

20. A DME transponder with a fixed delay of 50 micro-seconds, receives an interrogating signal from an aircraft 285 micro-seconds after transmission, making the slant range to the aircraft read:

(a) 23 NM;
(b) 46 NM;
(c) 42 NM.

21. A bearing accuracy of ± 3,5 degrees is guaranteed from each of two VOR's sited on the centre line of an airway 10 NM wide. In order to ensure that aircraft correctly using these facilities remain within the airway at midpoint, the facilities may not be further apart than:

(a) 84 NM;
(b) 168 NM;
(c) 210 NM.

22. Between Upington and Victoria West the aircraft is on radial 252 KMV where variation is 20 W. At the aircraft variation is 21 W. From the aircraft's position the heading to steer towards KMV (zero wind) is:

(a) 072 (T);
(b) 052 (T);
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23. A particular VOR station is undergoing routine maintenance. This is confirmed by:

(a) Transmitting a series of dots after each identification signal;
(b) The removal of the navigational feature;
(c) The removal of the identification signal.

24. On a VOR the full deflection of the deviation needle left or right represents a departure from the selected radial of:

(a) 5 degrees;
(b) 10 degrees;
(c) 2,5 degrees.

25. If a signal of two hertz was transmitted for one second, the physical space occupied by the signal would be:

    (a) 300 000 000 M;
    (b) 150 000 000 M;
    (c) 600 000 000 M.

26. When using a VOR facility with 050 set on the OBS, the CDI needle is central, but the TO/FROM indication is inoperative. If the OBS is now set to 060 and the needle is deflected to the right, the aircraft is on the:

    (a) 050 radial either flying away or towards the VOR;
    (b) 230 radial either flying towards the VOR;
    (c) 050 or 230 radial depending on which side of the VOR the aircraft is.

27. Full scale deviation of RNAV CDI in the approach mode is:

    (a) 1,25 NM;
    (b) 2,50 NM;
    (c) 5,00 NM.

28. When using RNAV in the approach mode, the distance between the parent VOR/DME and the final approach waypoint should not be greater than:

    (a) 10 NM;
    (b) 25 NM;
    (c) 50 NM.

29. The maximum range of search radar is dependant on the:

    (a) Radio frequency;
    (b) Pulse recurrence frequency;
    (c) Pulse width.

30. The minimum range of search radar is dependant on the:

    (a) Radio frequency;
    (b) Pulse recurrence frequency;
    (c) Pulse width.

31. The use of weather radar (ASR) when the aeroplane is on the ground is:

    (a) Prohibited;
    (b) Permitted but used with extreme caution;
    (c) Permitted in maintenance area only.

32. The brilliance of a Cathode Ray Tube (CRT) display is controlled by the:

    (a) 1st and 3rd anodes;
    (b) 2nd anode;
    (c) Grid.

33. On a Cathode Ray Tube using a horizontal time base, unwanted echoes or "grass" can be reduced or removed from the screen by the:

    (a) Graphite coating;
    (b) X plates;
    (c) Gain control.

34. An X channel DME transponder will not reply to a Y channel interrogation on the same frequency because the:

    (a) Spacing between the interrogation pulses is different;
    (b) Interrogation and reply frequencies are 63 MHz apart;
    (c) Random PRF which is unique to each aircraft.

35. The frequency band in which Secondary Surveillance Radar (SSR) operates is:

    (a) VHF;
    (b) UHF;
    (c) SHF.

36. A carrier wave with amplitude of 5V is modulated by an audio frequency with amplitude of 3 V. The depth of modulation is:

    (a) 40 %;
    (b) 60 %;
    (c) 167 %.

37. To double the range of an NDB the transmission power must be increased by a factor of:

    (a) 2;
    (b) 4;
    (c) 8.

38. Selecting a lower HF/RT frequency results in:

    (a) An increase of the critical angle;
    (b) An increase of the dead space;
    (c) A decrease of the skip distance.

39. Static interference increases with an:

    (a) Increase in frequency;
    (b) Decrease in frequency;
    (c) Decrease in wave length.

40. The bending of a radio wave by the Earth's surface is greatest on:

    (a) VLF;
    (b) LF;
    (c) MF.

41. With frequency modulated transmissions the:

    (a) Amplitude is constant and the frequency varies;
    (b) Frequency is constant and the amplitude varies;
    (c) Amplitude and frequency vary.

42. With frequency modulated transmissions the:

    (a) Amplitude is constant and the frequency varies;
    (b) Frequency is constant and the amplitude varies;
    (c) Amplitude and frequency vary.

43. An aircraft's DME receiver will not accept replies to its own interrogations that are reflected from the ground or clouds, because of the:

    (a) Random PRF which is unique to each aircraft;
    (b) Interrogation and reply frequencies being 63 MHz apart;
    (c) Interrogation pulses being transmitted in pairs.

44. When using HF for communications over a specified distance, transmissions at night should be done on frequencies almost half of the optimum day frequency because:

    (a) The ionosphere is lower at night requiring a higher critical angle which occurs at a lower frequency;
    (b) At night the reflection height increase and layer density decreases, using lower frequencies reduces the skip distance;
    (c) A lower frequency reduces the attenuation allowing the ground wave to have a greater range, so reducing the dead space.

45. The magnetic component of a radio wave emitted from a vertical aerial, travels in the:

    (a) Vertical plane;
    (b) The horizontal plane;
    (c) Vertical plane with the electrical component but ninety degrees out of phase.

46. Super High Frequency (SHF) is utilised for:

    (a) RADAR;
    (b) Communication;
    (c) ILS.

47. If wavelength is 3 cm, the frequency is:

    (a) 74 MHz;
    (b) 100 GHz;
    (c) 10 000 MHz.

48. The E layer in the ionosphere is also known as the:

    (a) Appleton layer;
    (b) Kennely-Heavyside layer;
    (c) Barret layer.

ANNEXURE B

ANSWER SHEETS

WORKSHEET 1 (BASIC RADIO THEORY)

1	C	11	A	21	B	31	A
2	B	12	C	22	A	32	A
3	C	13	C	23	C	33	C
4	B	14	C	24	A	34	C
5	A	15	B	25	A	35	A
6	B	16	A	26	B	36	B
7	B	17	A	27	C	37	C
8	B	18	B	28	A		
9	A	19	C	29	C		
10	C	20	A	30	A		

WORKSHEET 2 (ADF/NDB)

1	C	11	A	21	C	31	B
2	C	12	A	22	A	32	C
3	A	13	B	23	B	33	B
4	B	14	B	24	C	34	B
5	B	15	B	25	B	35	A
6	C	16	C	26	A		
7	C	17	C	27	C		
8	A	18	A	28	C		
9	C	19	A	29	B		
10	C	20	A	30	A		

WORKSHEET 3 (VOR)

1	C	11	B	21	B	31	A
2	A	12	C	22	B	32	C
3	B	13	A	23	D	33	A
4	B	14	B	24	B	34	B
5	C	15	C	25	C	35	C
6	A	16	C	26	B	36	A
7	B	17	B	27	C	37	C
8	C	18	A	28	C	38	B
9	C	19	B	29	B	39	A
10	A	20	A	30	B		

WORKSHEET 4 (ILS)

1	B	11	A	21	C		
2	A	12	B	22	A		
3	C	13	C	23	C		
4	C	14	B	24	A		
5	A	15	B	25	C		
6	B	16	A	26	B		
7	A	17	C	27	C		
8	B	18	A				
9	C	19	C				
10	B	20	B				

WORKSHEET 5 (BASIC RADAR)

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

WORKSHEET 6 (DME)

1	B	11	B
2	A	12	B
3	B	13	A
4	C	14	C
5	B	15	A
6	B	16	A
7	B	17	B
8	C	18	C
9	B	19	B
10	A		

WORKSHEET 7 (SSR)

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

WORKSHEET 8 (R ALT)

1	A
2	A
3	C
4	A
5	A

WORKSHEET 9 (ASR)

1	B	8	A
2	B	9	B
3	C	10	B
4	A		
5	C		
6	C		
7	B		

Mock Examination 1

1	B	26	A
2	B	27	C
3	A	28	B
4	C	29	B
5	B	30	A
6	B	31	C
7	A	32	C
8	C	33	A
9	B	34	B
10	B	35	B
11	A	36	A
12	B	37	B
13	A	38	C
14	A	39	B
15	B	40	A
16	C	41	B
17	B	42	C
18	C	43	C
19	B	44	C
20	B	45	B
21	B	46	A
22	B		
23	B		
24	A		
25	A		

Mock Examination 2

1	B	28	C
2	B	29	B
3	C	30	C
4	A	31	B
5	A	32	B
6	B	33	A
7	B	34	B
8	B	35	A
9	C	36	B
10	B	37	B
11	A	38	C
12	C	39	B
13	B	40	C
14	B	41	C
15	A	42	A
16	B	43	B
17	A	44	B
18	A	45	B
19	C	46	C
20	A	47	B
21	A	48	A
22	B	49	A
23	A	50	B
24	B	51	B
25	A	52	C
26	B	53	C
27	B		

Mock Examination 3

1	C	26	A
2	C	27	A
3	A	28	B
4	A	29	B
5	B	30	C
6	B	31	B
7	A	32	C
8	C	33	C
9	B	34	A
10	A	35	B
11	C	36	B
12	B	37	B
13	B	38	C
14	A	39	B
15	B	40	A
16	A	41	A
17	C	42	B
18	A	43	B
19	A	44	B
20	B	45	B
21	B	46	A
22	B	47	C
23	C	48	B
24	B		
25	B		