ROYAL AIR FORCE COSFORD

Nº 2 School of Technical Training

TRAINING NOTES

AIR RADAR Flt. AIR RADIO Sqn.

NO ____________ RANK ______________ NAME ___________

BW COS 10094

RADAR PRINCIPLES

L MECH (AR)

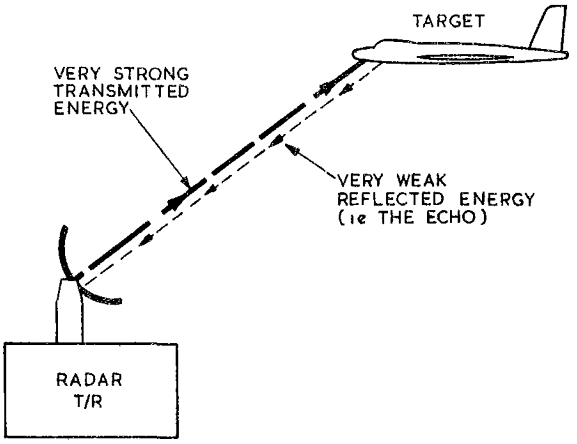
1. Introduction.

The word RADAR was derived from the initial letters of RADIO DETECTION AND RANGING, which describes the use to which radar was originally put. Today the word has a wider meaning embracing electronic systems which perform a wide range of tasks (eg range and bearing measurement; speed and drift measurement; identification). It must be understood, however, that the term "radar" is not applied to all systems which measure bearing or provide navigational information. Which systems are called "radar" and which ones are not is largely a matter of custom, or is determined by operational convenience or by servicing practice.

2. Classification of Radar Systems.

There are many ways of classifying radar systems but a fundamental classification is that which splits radar systems into PRIMARY and SECONDARY radars.

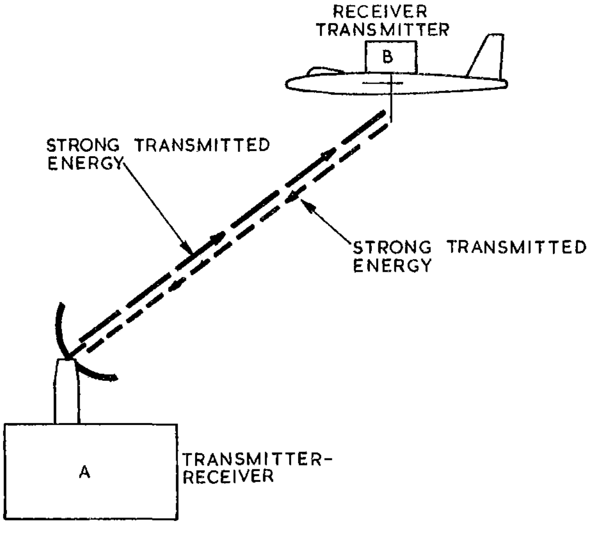
a. Primary Radar. A radar which transmits energy and then receives some of that same energy back again after it has been reflected by some object (eg an aircraft; a cloud; the ground), see Fig 1.



PRIMARY RADAR TRANSMITTER - RECEIVER

Figure 1

b. Secondary Radar. A radar "A" transmits energy which is received by another radar "B". Radar "B" then replies to "A" by transmitting energy which is received by Radar "A", (ie TWO radars working together and "communicating" with each other).



SECONDARY RADAR

Figure 2

3. Some Comparisons of Primary and Secondary Radar.

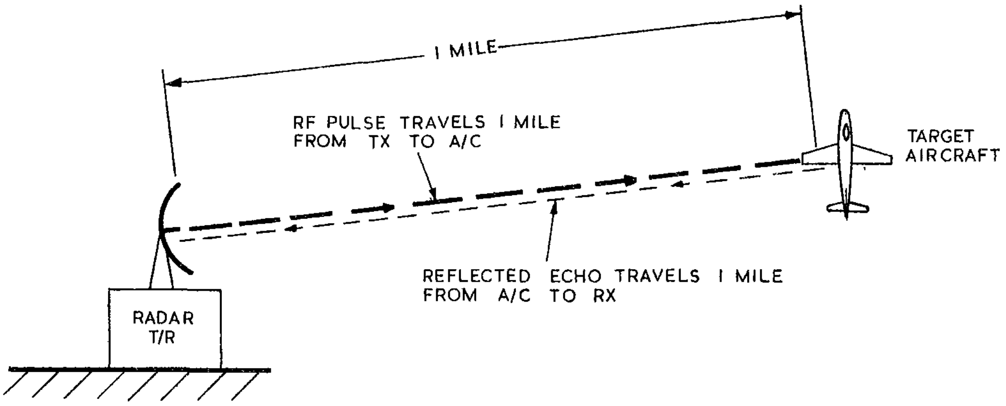
PRIMARY	SECONDARY
1. Only ONE radar required.	TWO radars necessary which work together.
2. Does NOT need the co-operation of its target.	MUST have the co-operation of another radar, as Fig 2.
3. High TX power needed to obtain moderate range.	Long ranges obtainable with very modest TX power.
4. Echos are received from all reflecting objects within range whether they are required or not.	No echos are received at any time. Replies are received only from another compatible radar.

4. Radar systems may also be classified by frequency (or wavelength), eg metric or centimetric radar; or by operational function, eg navigation radar, interception radar, identification radar, weather radar, radar altimeters etc. All such classifications have their uses and all the above will be encountered in practice.

RANGE AND ANGLE MEASUREMENT

5. Range Measurement

A very narrow pulse of RF energy is transmitted. Some of this energy is reflected from an object and is received by the radar which transmitted it. The time delay between transmission of the pulse and reception of the echo is proportional to the distance the pulse has travelled from the TX to the "target" and back to the RX. If the speed at which radio waves travel is known then the distance travelled can be calculated. The range of the target is equal to half the distance travelled by the RF pulse. See Fig 3.



RANGE MEASUREMENT

Figure 3

In Fig 3 the measured time between transmission and reception is 10.75 μ-seconds. As the speed at which radio waves travel is known to be 186,000 miles per second, the distance travelled by the pulse can be calculated and therefore the range of the target can be obtained.

A delay of 10.75 μ-sec will always be obtained from a target 1 mile (5,280 ft) distant

This period is known as the time of 1 Radar Mile.

As most airborne radars are calibrated in nautical miles, the time for 1 Radar Nautical Mile must also be calculated.

A delay of 12.36 μ-secs will always be obtained from a target 1 Nautical Mile (6,080 ft) distant.

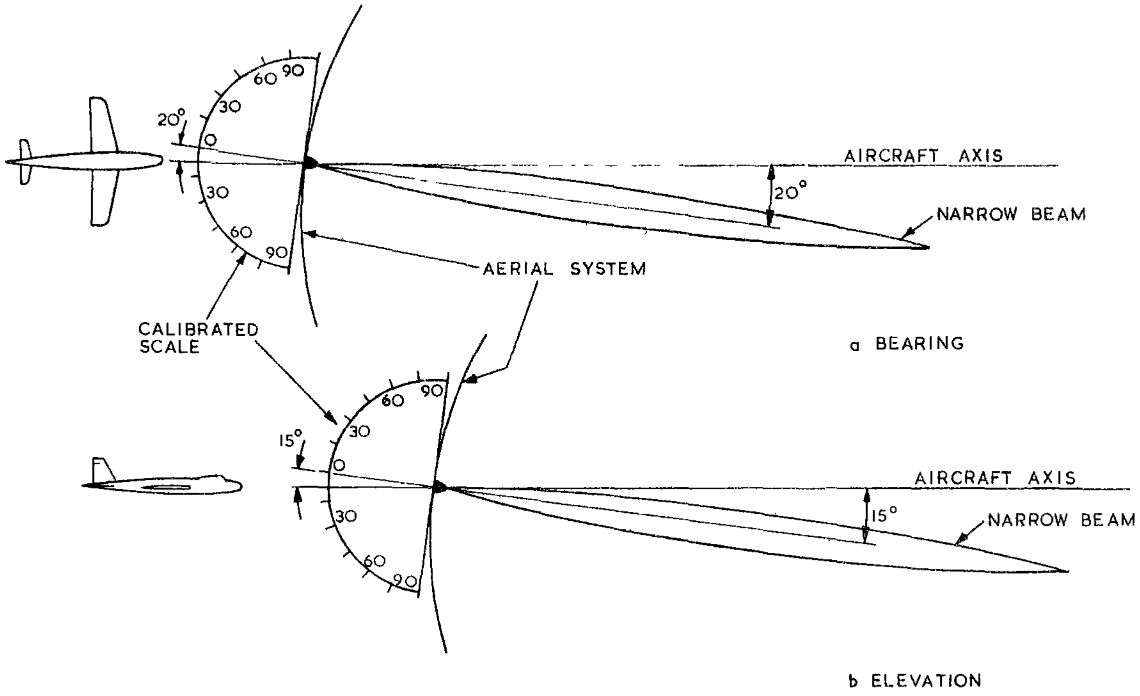
A delay of 247.2 -secs therefore represents a target range of 20 nautical miles.

6. Angle Measurement.

If you stand in a darkened room and then switch on a torch which has a narrow beam, only those objects on which the beam falls will be visible. You can tell, by the direction in which you are pointing the torch, whether the object illuminated is to the left or right, above or below the point at which you are holding the torch.

This is the principle of BEARING (ie angles sideways) and ELEVATION (ie angles UP or DOWN) measurement employed by most radar systems. The aerial system (or scanner) replaces the torch and a narrow beam of RF energy replaces the beam of light.

If a calibrated scale is fixed to the aerial system the angle (in degrees) that the aerial system is pointing away from a datum point can simply be read off the calibrated scale. See Fig 4.



ANGLE MEASUREMENT

Figure 4

The aerial system may be made to move from side to side in sequence, or up and down in sequence, or a combination of both. Aerial systems may also be made to rotate continuously in one direction. The movement of an aerial system in any pre-arranged pattern is known as SCANNING and such an aerial system is known as a SCANNER.

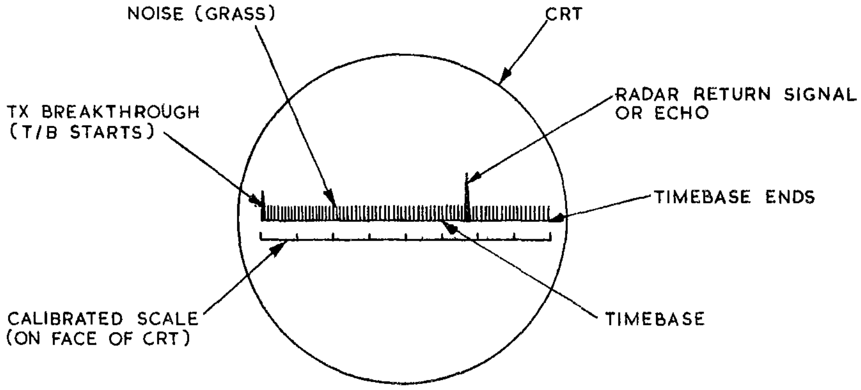
The reference from which angles were measured in Fig 4 was the aircraft centre-line or axis, therefore all readings were in degrees PORT or STARBOARD or UP or DOWN with respect to the aircraft centre-line. However, other reference points can be used instead of the aircraft axis; eg for BEARING measurement NORTH is often used as the reference so that the calibrations on the aerial system can take the form of a compass reading, ie 0° to 360°.

As it is not practicable for a radar operator to read angles directly off a scale on the scanner (generally inaccessible) some means of relaying the information from the scanner to the operator's position is required. This is achieved by the use of a suitable display system. All other information provided by the radar (eg range information) must also be displayed. Some simple radar displays will next be considered.

RADAR DISPLAYS

7. Displays Using Cathode Ray Tubes.

a. Type A Display.



BASIC TYPE "A" DISPLAY

Figure 5

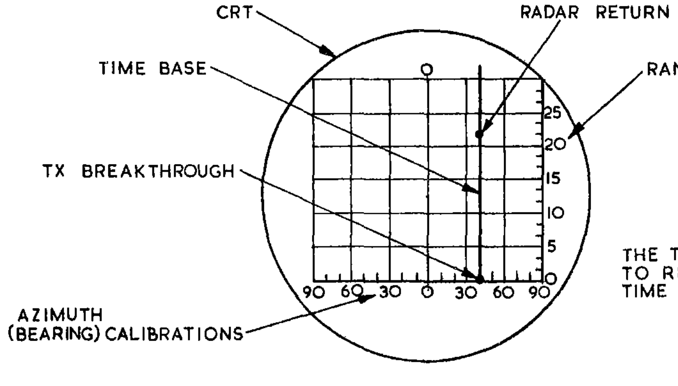
This type displays Range only and is the display used in most oscilloscopes. It is used to measure very short intervals of time (eg micro-seconds-µs). A spot of light is produced on a CRT screen by an electron beam and by deflecting the beam the spot is made to move across the screen to trace out a line. This is known as a TIMEBASE.

The timebase starts at the instant the TX fires and when an echo is received it causes the spot to be deflected forming a blip on the trace (known as a signal; or as a radar return; or simply as a "return") as shown in Fig 5. The time interval (in µsecs) between the start of the timebase and the blip is a measure of the range of the target. If the spot is made to move at a known constant speed across the screen, the scale can be calibrated directly in distance (ie Range - in Miles or N. Miles).

eg If a timebase is 247µsecs long then the MAXIMUM range it can measure (and display) is 20 N Miles. A blip appearing three-quarters of the way along it represents a target range of 15 N Miles.

NOTE It is important to realise that the physical length of the timebase is irrelevant, it is the electrical length (in µsecs) that determines the range which can be displayed.

b. Type B Display



THE TIMEBASE MOVES FROM LEFT TO RIGHT (AND BACK AGAIN) IN TIME WITH THE SCANNER

TYPE B DISPLAY

Figure 6

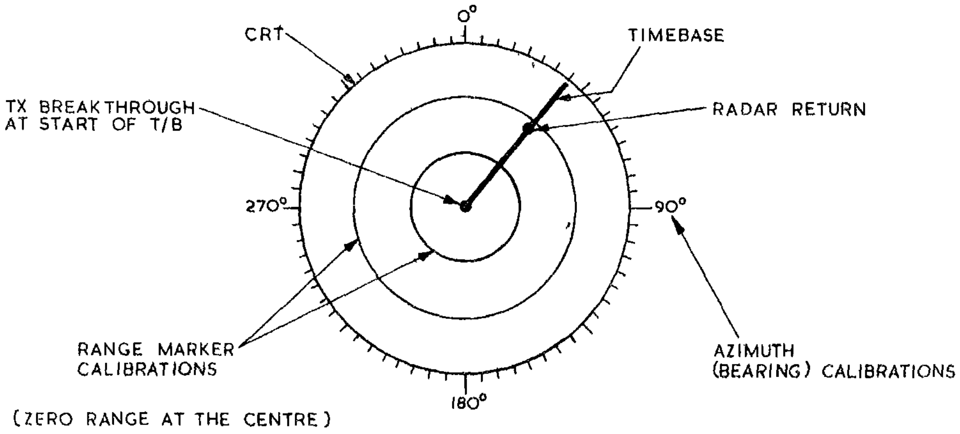
Range is measured in the same manner as in the type A display except that the timebase is vertical instead of horizontal. Zero range is normally at the bottom and the return signals may appear as an extra bright spot on the timebase instead of as a deflection of the trace.

Angles of azimuth (bearing) are measured by moving the timebase from side to side in time with the scanner so that the lateral position of the timebase represents the position that the scanner is looking in azimuth. The face of the CRT is calibrated in degrees (Fig 6) which match exactly the calibrations on the aerial system shown in the last lesson (Fig 4).

The lateral position of the timebase when the echo is received therefore represents the scanner position at the time when the target is illuminated by the radar beam.

The vertical position of the return therefore represents RANGE whilst the horizontal position represents AZIMUTH.

c. PPI Display



PLAN POSITION INDICATOR

Figure 7

When a scanner rotates continuously in one direction a display is needed in which the timebase also rotates continuously. If the timebase rotation is synchronised to scanner rotation then the timebase position represents the scanner position in azimuth. The PPI display provides this facility.

The rim of the CRT can be calibrated from 0° to 360°. 0° can represent aircraft heading (ie scanner looking forwards) or it can be made to represent NORTH by referencing it to a compass.

The timebase rotates about the centre of the CRT which generally represents zero range. Range is measured along the timebase (ie the distance of the radar return from the centre of the tube) and angle by the position of the timebase when a return signal is received. See Fig 7.

NOTE The three CRT displays discussed are shown in basic form. Additional information can be introduced (eg by the use of various types of marker) and some variations of these displays will be met in individual applications. These basic principles, however, remain valid.

8. Other Types of Display.

CRT displays have the great disadvantage that a skilled radar operator is often (but not always) required to interpret the information presented. To overcome this, many airborne radars use simple displays which give direct indications or readings which do not require interpretation. Such displays take the following forms:

a. Meter Display. A pointer read against a calibrated dial like a car speedometer.

b. Digital Display. Numbers on a drum visible through a window like a car mileometer. Both a and b are used to display range and speed in airborne radar systems.

c. Lamps. These are used to indicate the operational state of a system or to indicate specific events.

d. Flag Indicators. Generally have similar uses to lamps.

TERMS

9. A radar TX radiates RF energy for a short period of time. It then rests for a comparatively long time before radiating again, eg

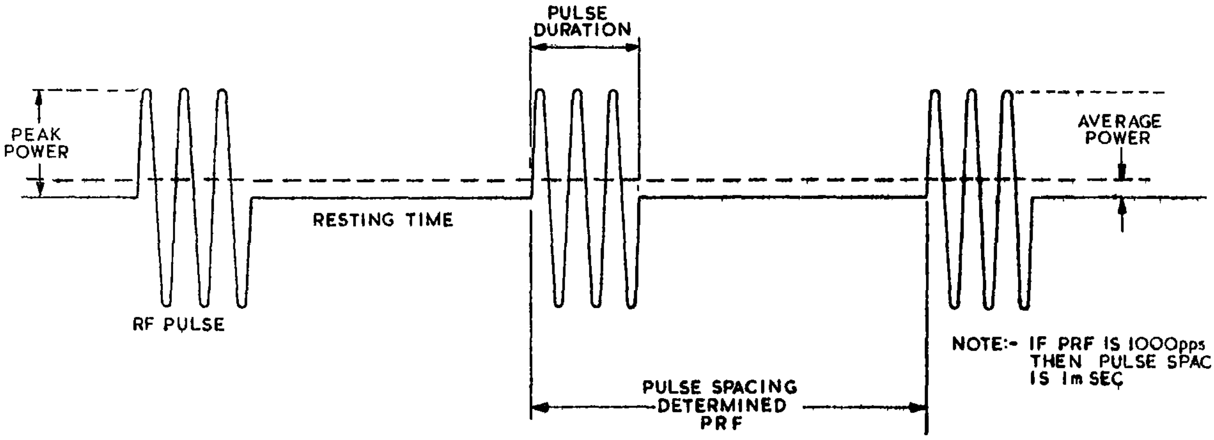


Figure 8

The terms associated with such a transmission are now considered.

10. Pulse Duration. (Pulse Width - PW). The length of time the TX is switched on to produce a "pulse" of radio frequency energy. Typical pulse widths; 0.5μsecs to 5μsecs, but pulse widths outside these values may be encountered.

INCREASED PW: INCREASES AVERAGE POWER
INCREASES MINIMUM RANGE

11. Pulse Recurrence Frequency - (PRF). The number of RF pulses transmitted in 1 second. Typical PRFs are 200 pulses per second (PPS) to about 2000 pps, though some will be encountered both above and below these values.

INCREASED PRF: INCREASES AVERAGE POWER
DECREASES MAXIMUM RANGE

12. Peak Power (PP). The power in watts contained in the RF pulse (ie the strength of the transmitted signal).

INCREASED PP: INCREASES AVERAGE POWER

13. Average Power (AP) or Mean Power. The TX power output averaged out to include the resting time. Generally very much lower than Peak Power. This is the power rating on which power supplies and component ratings in the TX are based.

DEPENDANT ON: PW, PP, and PRF an increase in any one of these will increase average power.

14. Minimum Range (of a radar system). The minimum range at which a target echo can be detected and displayed. DEPENDANT ON Pulse Width. Return signals cannot be received during the time the TX is firing (generally the RX is cut off during this time). The longer the PW, therefore, the greater the minimum range because the RX is cut off for a longer period of time. A radar designed to detect targets at very close ranges (eg an AI type radar) must therefore use a very short TX pulse width.

15. Maximum Range (of a radar system which measures range). In this context this means the maximum range at which a target echo can be DISPLAYED. It does not mean that the transmitted RF pulses only travel out a certain distance. It does not mean that return signals cannot be received from greater distances. It is referring to the capability of the radar system to DISPLAY signals and that is all.

DEPENDANT ON PRF - for accurate range measurement the target echo derived from one TX pulse must be received BEFORE the next pulse is transmitted. The time available, therefore, between transmission and reception (Page 2) gets less as the PRF gets higher. A radar designed to detect and display targets at long ranges (eg weather radar systems) must therefore use a fairly low PRF.

16. Maximim Range (of a radar which does NOT measure range). This generally refers to the maximum range at which the performance of the radar system is consistently reliable. The radar may or may not operate at greater ranges than that specified but any such operation could not be relied on.

RADAR FREQUENCIES

17. Radar systems operate at many different frequencies. We now consider the frequencies used in some typical radar systems and some of the reasons for the choice of these frequencies.

18. Frequency Bands. Frequencies have been grouped into "bands" for convenient reference. The most common bands used by airborne radar systems are given below:

BAND	FREQUENCY RANGE IN GHz	APPROX WAVELENGTH	ALSO REFERRED TO AS	USED BY
P.	0.25 - 1	1 m	UHF or METRIC	
L.	1 - 2	25 cm	UHF or CENTIMETRIC	TACAN IFF/SSR RADIO ALTIMETERS
S.	2 - 4	10 cm	SHF or CENTIMETRIC	SEARCH RADARS
C.	4 - 8	6 cm	SHF or CENTIMETRIC	RADIO ALTIMETERS
X.	8 - 12	3 cm	SHF or CENTIMETRIC	SEARCH RADARS eg Weather Radar ASV AI TAIL WARNING DOPPLER NAV RADAR
J.	12 - 18	2 cm	SHF or CENTIMETRIC	DOPPLER NAV RADAR

Centrimetric wavelengths are also known as microwaves. The choice of frequency to be used by a radar system is a complex matter depending on many factors. The following points are of importance however and would be amongst the factors considered by the designers.

19. Propagation Characteristics. Low frequencies are attenuated less during propagation than high frequencies. Low frequencies penetrate clouds better than high frequencies. Low frequencies are not reflected from small objects as well as high frequencies are. These facts mean that:

a. Lower frequencies are more suitable for reliable long range working (eg TACAN: IFF/SSR)

b. Lower frequencies are more suitable for radio altimeters where the penetration of dense cloud beneath the aircraft is necessary.

c. Higher frequencies are more suitable for search radars where good reflections from small objects is a requirement.

20. Power Available in each RF Pulse. The effective power in each TX pulse is related to:

a. The TX peak power output, and

b. The number of cycles of RF energy in the pulse

Where very narrow pulses are used (eg in the order of 0.5 s) the use of higher frequencies is of advantage because the higher the frequency the greater the number of cycles in the TX pulse and the greater the effective power. This in turn means stronger returns from small or distant objects.

21. Physical Size of the Aerial System. The physical size of the aerial is inversely proportional to the frequency therefore the higher the frequency the smaller the aerial required. This is of particular importance in the following cases:

a. Where it is required to focus the RF energy into a narrow beam, either

(1) To concentrate all the TX energy in one direction in an effort to obtain longer range, or

(2) To allow accurate measurement of angles (Page 3) and

b. Where a scanning aerial system (or scanner) is required. This is because the moving parts get smaller and lighter as the frequency used gets higher.

It will be apparent that the design of any radar system is always a compromise between many conflicting factors; eg, a low frequency for long range and a high frequency for good reflections from targets. The designer's task is to find the best compromise to achieve the objective in view.

BASIC OSCILLATOR AND BASIC TRANSMITTER

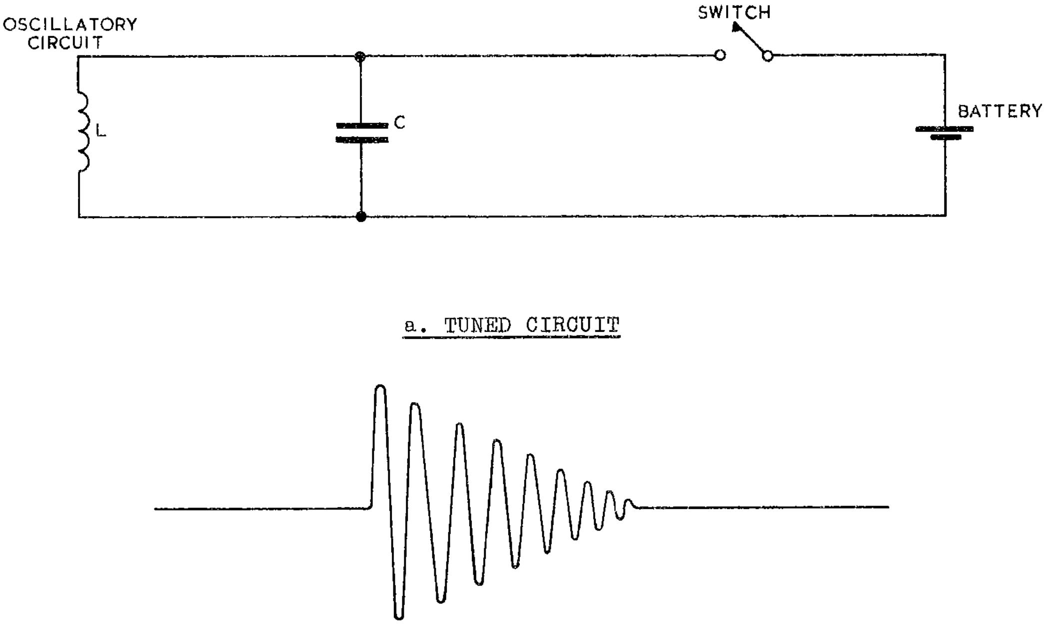
22. Introduction

The heart of every transmitter is an oscillator and at least one oscillator is used in almost all receivers. Oscillators are also used extensively in radar test equipment.

Oscillators can generate sine waves or square waves or sawtooth waveforms; the type of signal generated depends on the type of circuit employed.

Here we are concerned only with the basic sine wave oscillator using a tuned LC circuit to determine the frequency of oscillation.

23. Damped Oscillations



a. TUNED CIRCUIT

b. DAMPED OSCILLATION

Figure 9

Refer to Fig 9a. The switch is closed momentarily and capacitor C is charged from the battery. The battery is then disconnected by opening the switch again. The following action now takes place:

a. C will discharge through L.

b. A magnetic field builds up around L due to this discharge current.

c. When C is fully discharged the magnetic field around L collapses.

d. The collapsing magnetic field cuts the coil L and generates a current which causes C to become charged in the opposite polarity (to the original charge from the battery).

e. C then discharges through L, the discharge current flowing the opposite way this time.

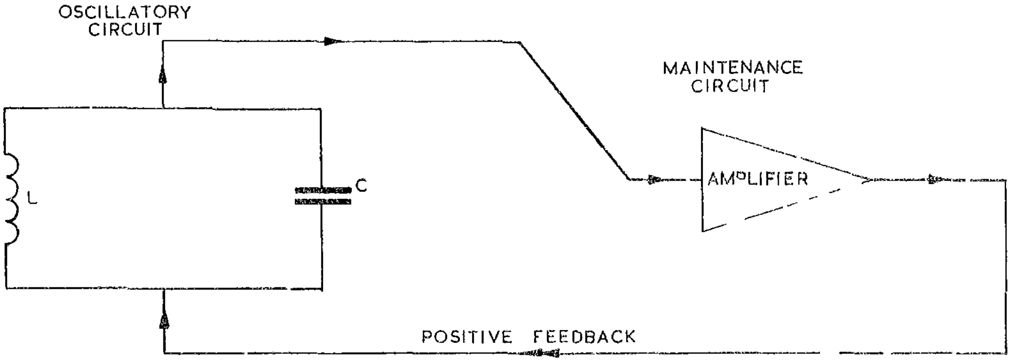
f. A magnetic field builds up (in the opposite sense to the original one) around L.

g. When C is fully charged this magnetic field collapses.

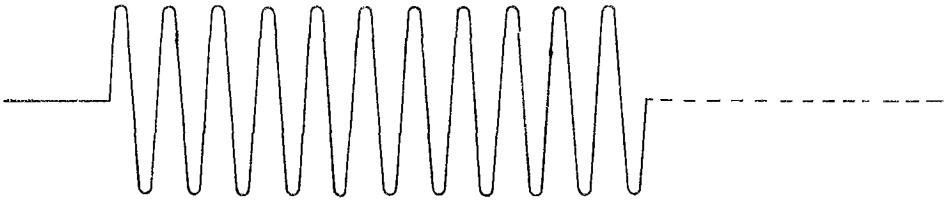
h. The collapse of the magnetic field causes C to charge in the original polarity again.

The oscillatory action just described would continue indefinitely if the circuit had no resistance and therefore no losses. In practice of course the circuit does have resistance therefore the oscillations get smaller and soon die out altogether. This is known as a damped oscillation (Fig 9b). The frequency of the oscillation is determined by the values of L and C.

24. Continuous Oscillations



a. TUNED CIRCUIT AND AMPLIFIER



b. CONTINUOUS OSCILLATIONS

Figure 10

If the losses in the tuned circuit can be compensated for then the oscillations will continue. This is achieved by amplifying the oscillations and then feeding some of the amplified oscillations back to the tuned circuit to make up for the losses (Fig 10). Such feedback is known as positive feedback because its phase is such as to assist the original oscillations (ie it is in phase with the original oscillations).

The oscillator can now be seen to consist of TWO distinct parts:

a. The oscillatory circuit, and

b. the circuit which maintains the oscillations known as the maintenance circuit.

25. Oscillator Output Amplitude

The amplitude of the positive feedback must be large enough to make up for the losses otherwise the oscillations will die out, but not so large as to cause the amplitude of the oscillations to rise excessively. Correct design of the maintenance circuit ensures that a reasonable amplitude of output is obtained and (more important) that the output amplitude remains constant.

26. Oscillator Frequency.

The frequency of the oscillations produced is determined by the tuned circuit, ie the values of L and C.

27. Frequency Stability

The frequency of the oscillations should be stable (ie should remain constant during operation). Certain design features may be used to improve stability and may be used singly or in combination. Some such design features are:

a. The use of stabilised power supplies.

b. To feed the oscillator output via a circuit which puts a constant load on the oscillator (ie a buffer amplifier).

c. To enclose the tuned circuit in a temperature controlled oven.

d. To isolate the oscillator from vibration.

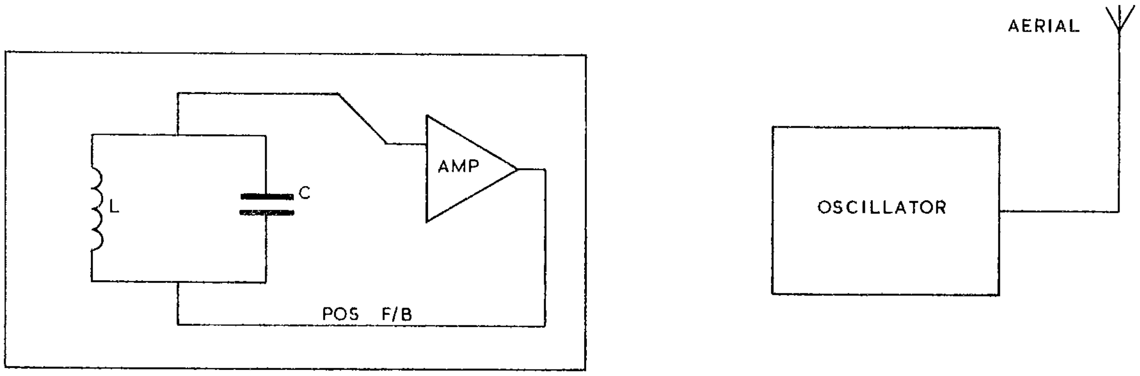
e. The use of a crystal as the tuned circuit instead of a coil and capacitor.

Refer to Fig 9. The energy from which the damped oscillations are obtained was derived from a DC supply, ie the battery.

Refer to Fig 10. The energy from which the continuous oscillations are obtained is derived from a DC supply, ie the DC supply which operates the amplifier.

It can be said, therefore, that an oscillator is a device for converting DC energy into AC energy of a desired frequency.

28. Basic Transmitter



a. OSCILLATOR

b. TRANSMITTER

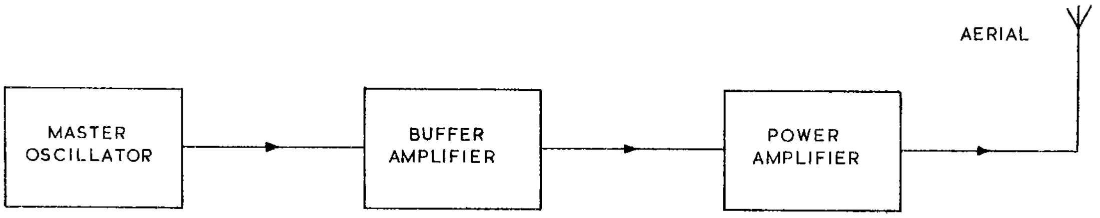
Figure 11

Refer to Fig 11. We now regard the oscillator (Fig 11a) as a single block (Fig 11b) and if it is connected to an aerial as shown, radiation will take place. This is the basis of all transmitters.

Disadvantages: Power output is limited.
Frequency stability poor because the load which the aerial imposes on the oscillator is not constant.

29. Improved Basic Transmitter.

Master Oscillator-Power Amplifier TX.



MOPA Transmitter

Figure 12

Refer to Fig 12. The purpose of the Buffer Amplifier is to provide a constant load on the oscillator to improve frequency stability. The power amplifier is included to provide high power output, it may consist of one or more stages depending on the output power required.

MODULATION

30. Introduction.

When an electric current flows in a wire a magnetic field is built up around the wire. If the current is an AC then the magnetic field rises in one sense, falls to zero, then rises in the opposite sense in time with the reversals in the direction of current flow. This you know already from your basic phase. But what happens if the frequency of the AC is increased to the point where the rise and fall of the magnetic field around the wire cannot keep up with the reversals of current flow in the wire? The answer is that the magnetic field variations are pushed away from the wire; they then become independent of the wire and travel outwards away from the wire entirely on their own. They are said to be RADIATED and are known as ELECTRO-MAGNETIC waves. Once radiated, they are capable of travelling great distances. The higher the frequency of the AC, the easier radiation takes place.

There is no clear cut frequency at which radiation starts to take place but, for practical purposes, frequencies below 20kHz do not radiate sufficiently well to be used for this purpose. As most of the frequencies below 20kHz are audible, these frequencies are termed AUDIO frequencies. As frequencies higher than 20kHz are suitable for radiation, they are termed RADIO frequencies. These two frequency bands are generally known as AF and RF. The radar frequencies discussed on page 7 of these notes are examples of very high radio frequencies.

31. The Need for Modulation

It can now be understood that the basic transmitters shown in Figs 11 and 12 must transmit RF energy. A continuous transmission of RF energy (known as continuous wave or CW) does NOT, however, carry any intelligence (ie information).

Information can take many forms, eg sounds as in radio telephony (RT) and in radio broadcasting; pictures as in TV broadcasting; intervals of time as in wireless telegraphy (WT) where codes (eg the Morse code) are used.

All the above information can be sent (ie transmitted) by wire or cable, but NONE of it can itself be RADIATED. Such information can however be superimposed on a RF signal by causing the RF signal to vary in some way. The high frequency RF signal then acts as a carrier of the information.

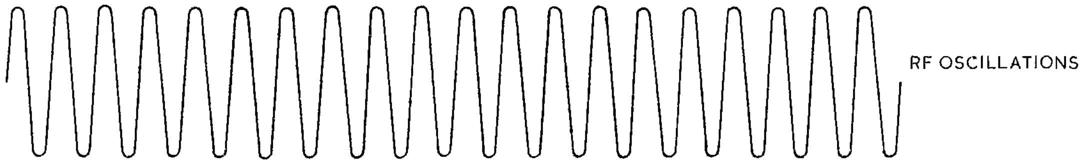
The process of impressing information onto a RF signal is known as MODULATION. The term modulation is also used to describe the variations in the RF which result from the process of modulation.

The information to be transmitted is converted into an electrical signal, known as the Modulating signal. The RF signal, known as the Carrier wave is then modulated by it before being transmitted.

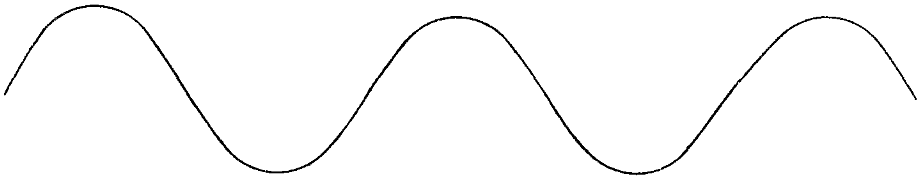
32. Types of Modulation

RF signals can be modulated in a number of ways. Some examples are now considered.

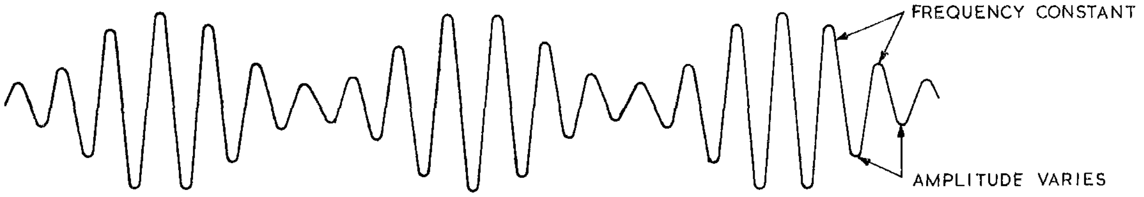
a. Amplitude Modulation. A RF signal is amplitude modulated by an AF signal. The AMPLITUDE of the RF is made to vary at the AF, eg



a. UNMODULATED RF (CW)



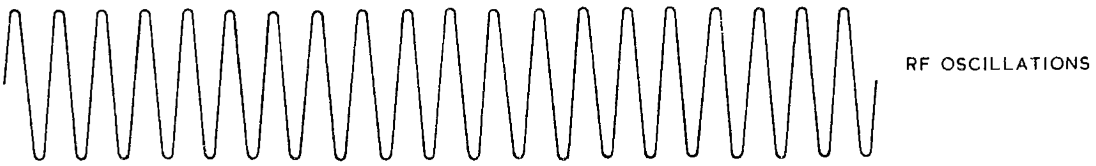
b. MODULATING SIGNAL (AF)



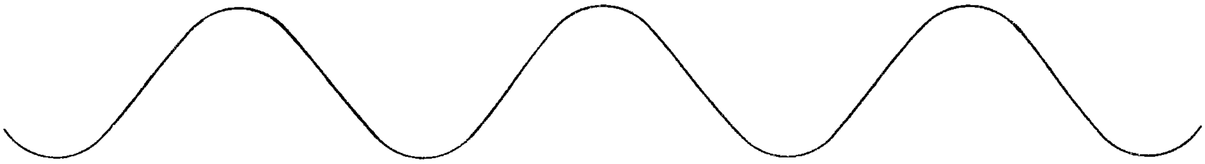
c. AMPLITUDE MODULATED RF (MCW)

Figure 13

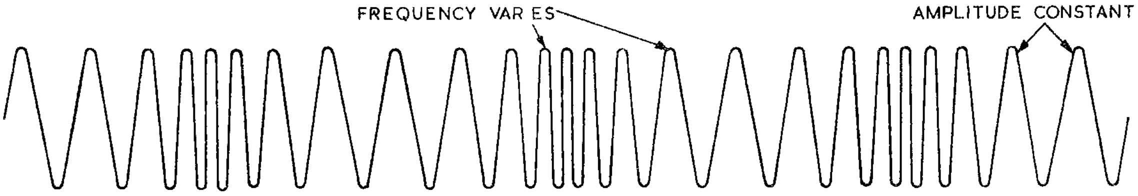
b. Frequency Modulation. A RF signal is frequency modulated by an AF signal. The FREQUENCY of the RF is made to vary at the AF, eg



a. UNMODULATED RF



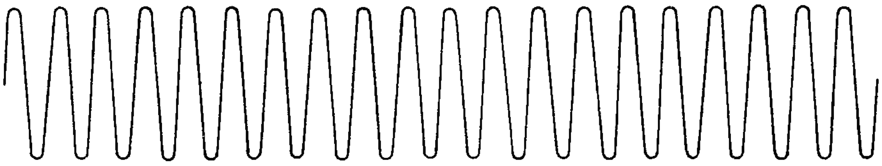
b. MODULATING SIGNAL (AF)



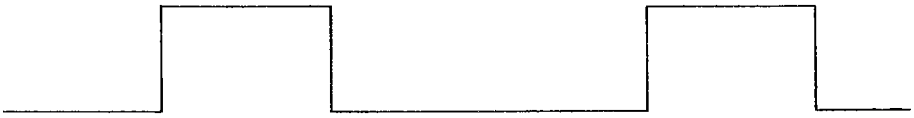
c. FREQUENCY MODULATED RF

Figure 14

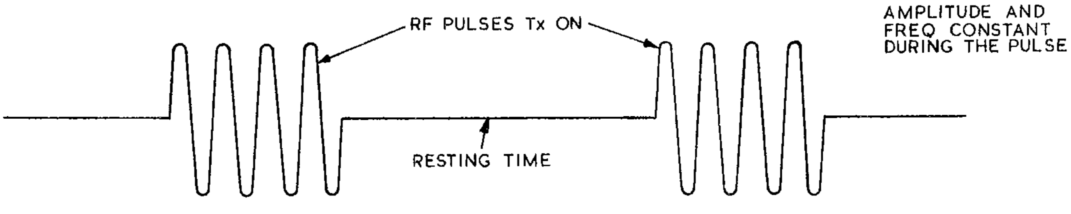
c. Pulse Modulation. This is the type of modulation used in most Radar systems. It is really an extreme form of amplitude modulation. The RF signal is switched ON and OFF by the modulating signal which is normally a voltage or current pulse, eg



a. UNMODULATED RF



b. MODULATING SIGNAL (ie SQUARE PULSES)



c. PULSE MODULATED RF

Figure 15

33. Basic MOPA Amplitude Modulated Transmitter.

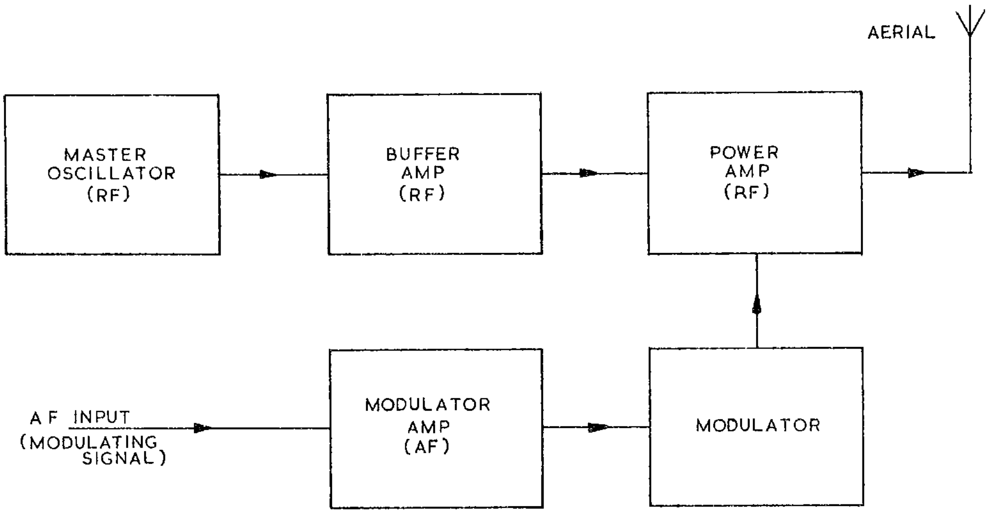
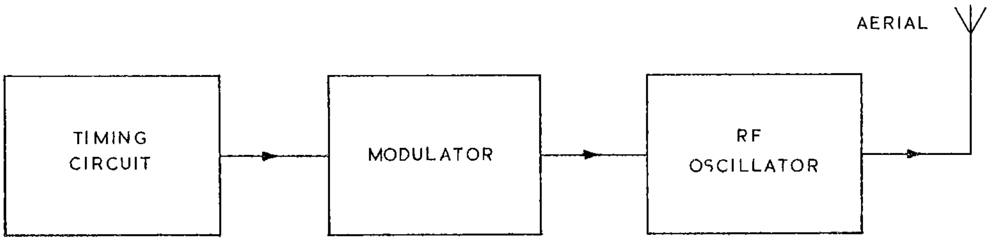


Figure 16

Refer to Fig 16. We now have a Block diagram of a practical AM transmitter. The AF input could be from a microphone so that speech or music could be transmitted. The modulator amplifier amplifies the input signal to the necessary power to drive the modulator, the modulator causes the amplitude of the RF output to vary at the modulating frequency.

SIMPLE RADAR TRANSMITTER

34. Radar transmitters vary greatly in detail, but the basic features identifiable in most radar transmitters are shown in Fig 17.



SIMPLE RADAR TX

Figure 17

The only important difference between this transmitter (Fig 17) and the AM transmitter in Fig 16 is the addition of the TIMING circuit. The radar transmitter could have a buffer amplifier and/or power amplifier in the same way as in Fig 16, the only real difference is in the timing circuit and in the type of modulator used.

35. Timing Circuit

Purpose - To determine the PRF of the radar system. The type of circuit used is generally a free-running square wave oscillator (eg an astable multivibrator). The output may be square waves or pulses.

36. Modulator

Purpose - To determine the Pulse Duration of the radar transmitter. May also determine the Peak Power output in some systems. The type of circuit used may be a pulse amplifier or it may be a pulse forming network (eg a delay line and transformer). The modulator produces one pulse (either of voltage or of current) of the correct width and amplitude every time it receives a trigger pulse from the timing circuit.

37. RF Oscillator

Purpose - As in any transmitter, to determine the frequency of the radiated RF energy. The output from a radar transmitter is similar to the example shown in Fig 15.

CENTIMETRIC OSCILLATORS AND TRANSMITTERS

38. Introduction

The oscillators discussed so far consist of a tuned circuit and an amplifier connected in such a way that continuous oscillations are produced. They are suitable for producing audio frequencies and, with slight changes, radio frequencies up to about 1000 MHz. However, because losses increase as frequency increases, oscillators using separate components eventually become unsuitable. Specially designed and constructed oscillators have then to be used.

The basic difference between the oscillators previously discussed and these special centimetric oscillators is that the ordinary oscillator uses a separate valve and tuned circuit whereas the centimetric oscillator consists of a specially constructed valve and tuned circuit in unit. The centimetric tuned circuit itself is generally a small cylinder which possesses some inductance and some capacitance. Such a tuned circuit is known as a resonant cavity. If the physical size of the resonant cavity is altered, the frequency of oscillation is also altered. This means that centimetric oscillators can be made to be tunable. As metric and centimetric wavelengths require the use of different techniques, radar systems are often classified as Metric or Centimetric.

39. Types of Centimetric Oscillator

Only the two types commonly used in airborne radar systems will be considered.

a. The Magnetron. A special centimetric oscillator in which the valve and the tuned circuit are combined. A very strong magnetic field is provided by a permanent magnet and this causes energy to be given to the tuned circuit directly whenever the valve conducts. Magnetrons are usually designed to operate at one frequency only but some tunable ones are obtainable.

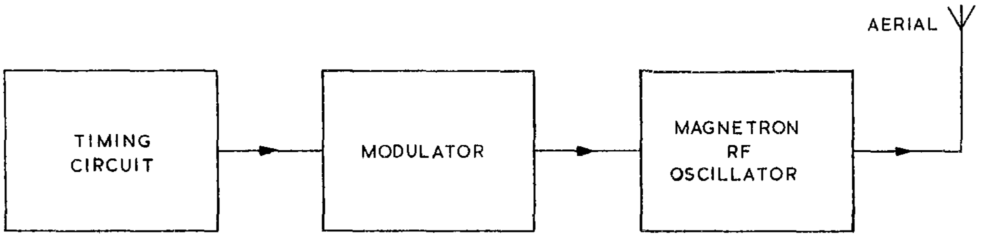
Use. As a High Power pulsed RF oscillator for use in the centimetric bands. Most current centimetric radars use a magnetron as the transmitter oscillator.

b. The Reflex Klystron. A special centimetric oscillator where the valve and the tuned circuit are essentially in one unit (though in some cases the valve can be separated from the tuned circuit). The reflex klystron makes use of a strong electric field to make the valve current give energy directly to the tuned circuit when the valve is conducting. Reflex klystrons are generally tunable over a band of frequencies either by adjusting the tuned circuit or by adjusting the strength of the electric field. Both methods are used in most applications.

Use. As a low power RF oscillator in the centimetric bands. It is not normal practice to use reflex klystrons in airborne radar transmitters but, as will be seen shortly, they are used extensively in centimetric radar receivers.

c. Semi-conductor Microwave Oscillators. These are now being introduced into new radar systems. They are low power devices, therefore demanding new techniques when used as radar transmitters. They are not dealt with further on this course.

40. Centimetric Radar Transmitter



CENTIMETRIC TX

Figure 18

There are two important differences between this transmitter and the one shown in Fig 17:

a. The type of RF oscillator used, and

b. The different techniques employed in the handling of microwaves.

T/R SWITCHING

41. Introduction

It will be recalled that a primary radar system receives some of the same energy which is transmitted, after reflection by some object. It follows therefore that transmitted and received frequencies are the same.

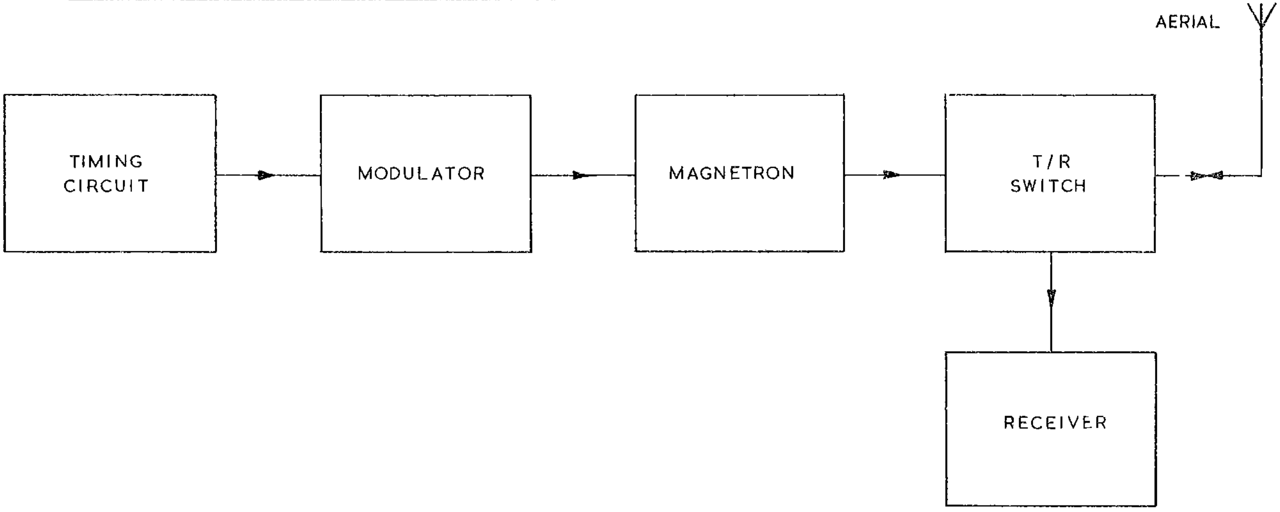
For most applications it is required that the same aerial is used for transmission and reception so that both the transmitter and the receiver must be connected to the one aerial.

As the transmitted and received frequencies are the same, some kind of switch is required to connect the transmitter to the aerial, whilst isolating the receiver, during the transmission time. Likewise, the switch must connect the receiver to the aerial, whilst isolating the transmitter, during the reception time.

42. Type of Switch Required

It will be appreciated that a mechanical switch cannot move fast enough for this purpose, therefore an electronic switch is necessary. The circuits used differ in detail but they all involve the use of a special valve or semi-conductor diode which is capable of being switched on by the high power transmitter pulse. They remain switched off at all other times. This switching capability is then used to achievo the purpose stated in para 41 (ie switched ON - TX connected to aerial; switched OFF - receiver connected to aerial).

43. Primary Radar Transmitter - Receiver



T/R Switch in Centimetric TX

Figure 19

During transmission, energy is routed from the magnetron to the aerial by the T/R switch. During reception the T/R switch routes energy from the aerial to the receiver.

44. Secondary Radar and T/R Switching

Although secondary radars do use common aerials for transmission and reception, it should be remembered that the transmitter and receiver frequencies are always different. Different techniques, based on selective tuned circuits, can therefore be used to achieve the same objectives as the T/R Switch in a primary radar system. No positive switching system (such as that described for primary radar) is therefore required in secondary radar systems.

45. A T/R switching system may also be called a DUPLEXER in some radar systems. The devices used as electronic switches (as described in para 42) include T/R CELLS, T/B CELLS, PIN DIODES, FERRITE materials and tuned lengths of transmission line.

AERIALS

46. Introduction

It has been seen already that when a wire is carrying radio frequencies, some radiation takes place. The amount of radiation (for a given RF current in the wire) is not however the maximum possible unless the wire has certain properties. A wire (or rod) designed to radiate RF energy efficiently is known as an AERIAL or as an ANTENNA.

Aerials may radiate energy equally in all directions (ie they may be omni-directional) or they may radiate more energy in one direction than in another. Such an aerial is said to be directional.

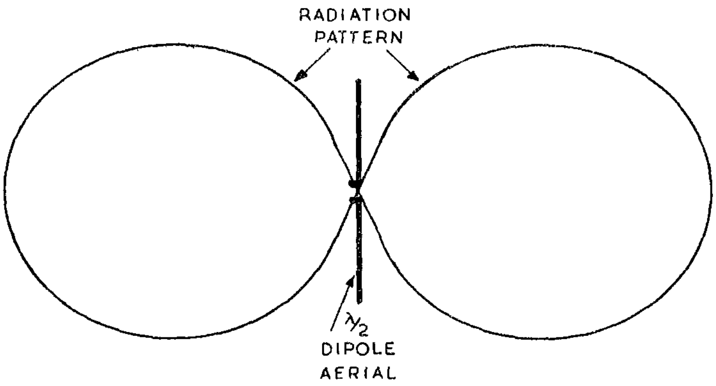
47. Types of Aerial

There are very many types of aerial but only those most commonly used in airborne radar systems are covered here:

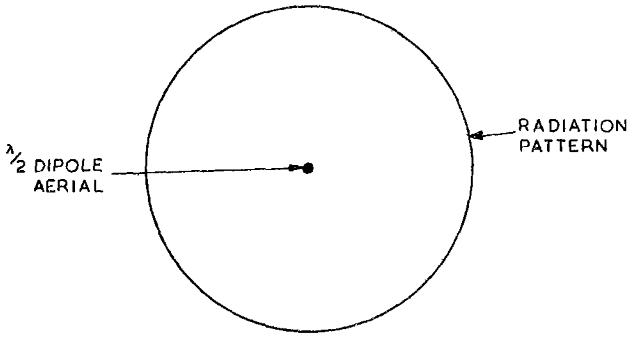
a. The Half-Wave Dipole

Generally a rod, the length of which is equal to half the wavelength of the RF to be radiated. The aerial is therefore tuned to a certain frequency but the tuning is not "sharp". This means that the aerial can radiate a band of frequencies instead of just a single frequency ie the aerial is said to have bandwidth.

The radiation patterns for a vertical half-wave dipole are shown in fig 20. A diagram depicting radiation patterns is known as a Polar Diagram.



a. VERTICAL POLAR DIAGRAM



b. HORIZONTAL POLAR DIAGRAM

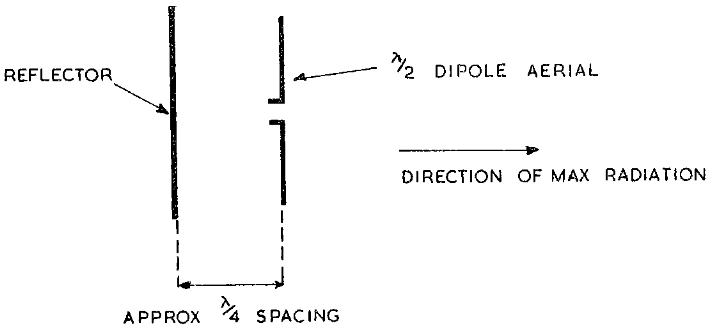
Half-wave ($\frac{\lambda}{2}$) Dipole Polar Diagrams

Figure 20

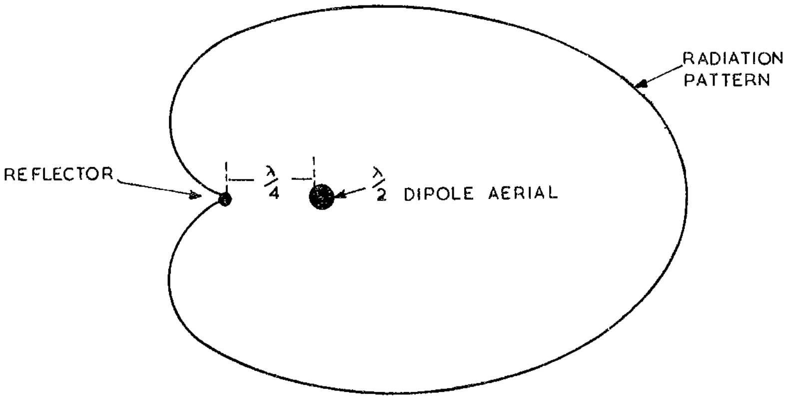
b. Half-Wave Dipole with Parasitic Elements

If another wire or rod is placed near a half-wave dipole aerial the shape of the radiation pattern (polar diagram) is altered. Some examples follow:

(1) The Reflector



a. DIPOLE AND REFLECTOR

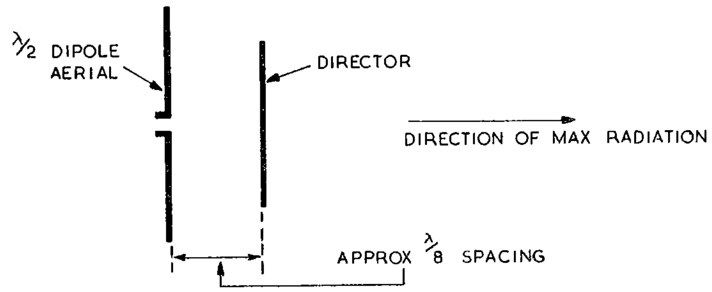


b. HORIZONTAL POLAR DIAGRAM

Figure 21

The reflector is always slightly longer than the dipole. Radiation is improved in the direction the dipole is looking and reduced "behind" the reflector. Only ONE reflector is used with the dipole.

(2) The Director



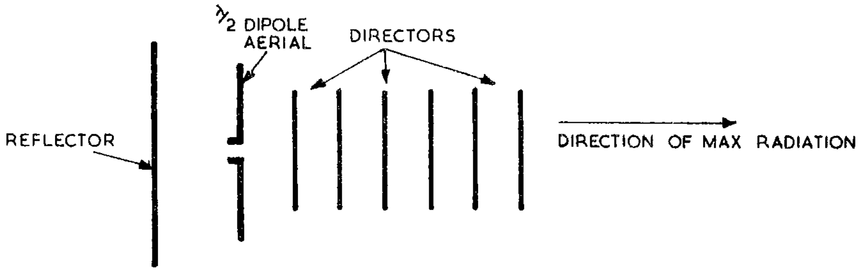
DIPOLE AND DIRECTOR

Figure 22

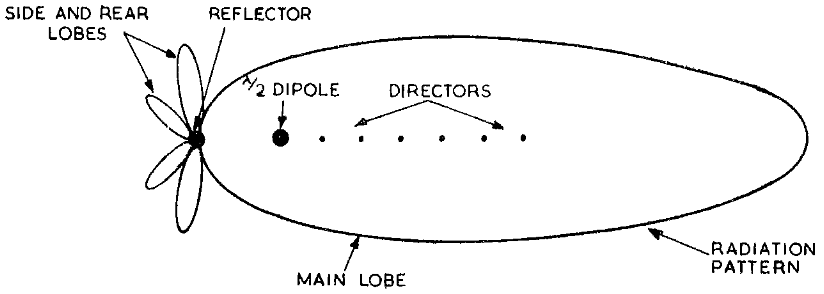
The horizontal polar diagram is similar to that in fig 21b. Directors are always slightly shorter that the dipole. Radiation is improved in the direction the director is looking and reduced "behind" the dipole. More than one director may be used with one dipole, the greater the number of directors the greater the directional properties of the aerial. The number of directors which can be used is limited by factors beyond the scope of these notes.

It is possible to use ONE reflector and a number of directors with one dipole at the same time to give very good directional properties. Such an aerial array is known as a YAGI array. (eg Television Aerials)

(3) Combination of Reflector and Directors



a. COMPOSITION OF YAGI ARRAY



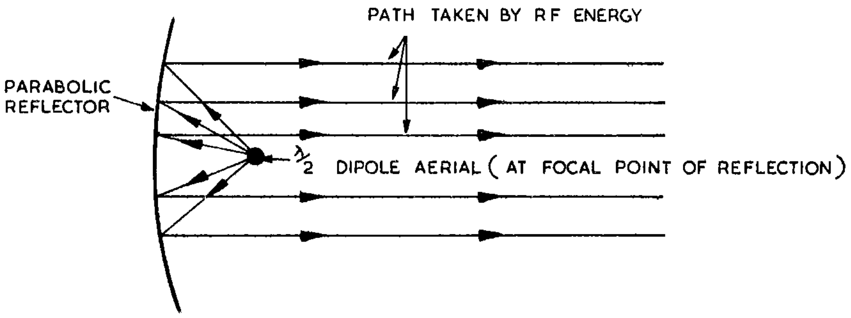
b. HORIZONTAL POLAR DIAGRAM

YAGI ARRAY

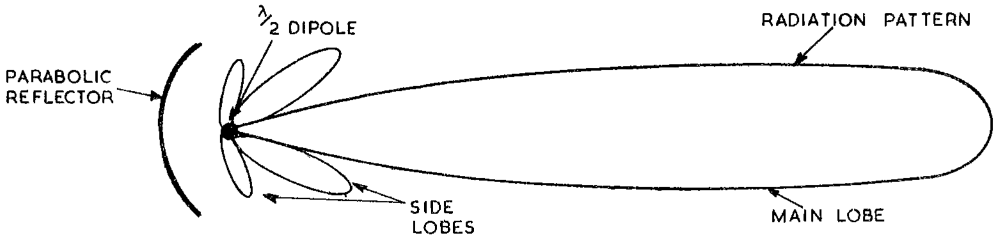
Figure 23

The direction of strongest radiation is known as the main LOBE of the radiation pattern. Side and rear lobes are always present (though unwanted) because it is not possible to eliminate them completely.

c. Half-Wave Dipole with Parabolic Reflector



a. COMPOSITION



b. POLAR DIAGRAM

DIPOLE WITH PARABOLIC REFLECTOR

Figure 24

Figure 24 shows a typical aerial system used in a centimetric search radar where a very narrow beam is required. The size of the dish (ie parabolic reflector) must be very large compared to the size of the dipole. It can now be seen why the size of an aerial system is so dependent on the frequency in use.

48. Although we have approached aerials from the point of view of their transmitting properties, all the foregoing refers equally to their receiving properties. Thus, an omni-directional aerial receives signals equally well from any direction, whilst a directional aerial receives signals from one direction better than it does from other directions. The polar diagram shows the directional properties (both for transmitting and receiving) of any aerial system.

RF TRANSMISSION LINES AND PROPAGATION

49. Introduction

The distance between a transmitter and the transmitter aerial may be considerable, similarly between a receiver aerial and the receiver. In both cases it is essential that RF energy is conveyed between the aerial and the appropriate unit with minimum loss. The special connectors designed to convey RF energy from one place to another with minimum losses are known as transmission lines. The two types of RF transmission line most commonly used in airborne radar systems are now described.

50. Types of RF Transmission Line

a. Co-axial Cable

This cable consists of a centre conductor surrounded by insulating material (eg polythene).
A An outer conductor in the form of metal braid is wrapped around the insulating material. Another layer of insulating material then covers the outer conductor to give protection (eg TV aerial cable). Co-ax is precision made cable which must not be damaged by over tight clamping or by over sharp bending, it must also be properly connected at each end using the proper type of termination. Failure to observe these requirements will result in severe losses of RF energy. This type of cable is used as aerial connectors on most metric radar systems.

b. Waveguides

At centimetric wavelengths co-axial cable becomes inefficient as losses become excessive. Some other type of connector is therefore required. A suitable connector is the waveguide. This is a hollow tube which may be either circular or rectangular in cross-section. The RF energy travels along inside the tube with few losses. Correct termination is once again essential as is the necessity to avoid denting or bending waveguides. Where sections of waveguides are joined the joints must be properly made with the appropriate sealing rings fitted. Foreign matter must never be allowed to enter waveguides. Most waveguides in use are of the rectangular type but circular sections are used in rotating joints in the scanners of centimetric search radars.

51. Propagation of Radio Waves

We have seen that once radiated, electromagnetic waves (consisting of an electric and a magnetic field), travel outwards away from the aerial. The medium in which they travel is still unknown but it has been named the "ether". It is known however that radio waves will travel through the atmosphere and also in space (ie a vacuum), unlike sound waves which will not pass through a vacuum. It is also known that radio waves pass through non-conducting materials such as wood, plastic, brickwork etc.but that they do not pass through conducting materials like metal. (Sound waves of course pass through all these materials). This property (ie radio waves do not pass through conducting materials) is used to contain radiation in one area, or to exclude radiation from a particular area. The process is known as screening.

Most substances reflect radio waves to some extent, the amount of reflection depending on the size of the object, the frequency (wavelength) of the radio wave and of course the material from which the object is made. Metal objects are the best reflectors of RF energy.

Generally speaking, the shorter wavelengths are reflected better than longer wavelengths. Longer wavelengths tend to "wrap around" an object in their patch and then continue onwards, they also bend around corners and will follow the curvature of the earth. Shorter wavelengths are easily reflected and they also travel in straight lines. All the radar frequencies discussed are of sufficiently short a wavelength to possess the property of travelling in straight lines and of being easily reflected.

BASIC RECEIVER AND RECEIVER TUNING

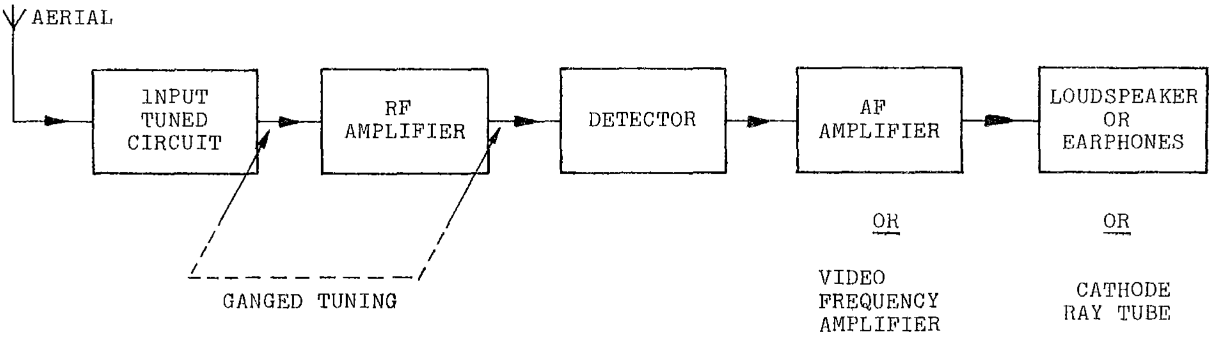
52. Introduction

When radio waves cut a conductor the electric and magnetic fields (which make up the radio wave) cause small RF currents to flow in the conductor. An aerial is of course a conductor and when used in this way is called a Receiver Aerial. The small signals induced in the aerial are then fed to the receiver along a transmission line.

A receiver is a device which accepts the RF from an aerial, extracts the information which is carried by the RF and converts it into the required form. eg A broadcast receiver picks up a BBC radio transmission on 200 kHz; it extracts the Audio Frequency signals with which the RF is modulated in the transmitter; it then converts these AF signals back into sound waves by means of a londspeaker.

53. Block Diagram of Basic Receiver

This type of RX is known as a TRF (Tuned Radio Frequency) receiver. May also be known as a "straight" receiver.



TRF RECEIVER

Figure 25

a. Input Tuned Circuit

Purpose - to select the required RF from the many different RF signals which are always present in the aerial. This will be a tuned LC circuit. To allow this circuit to be tuned to different frequencies the value of either L or C is variable. Normally C would be a variable capacitor. The control knob of the variable capacitor is then the RX Tuning control.

b. RF Amplifier

Purpose - to amplify the very weak RF signals selected by the input tuned circuit. This stage must be tuned to the same frequency as the input tuned circuit. If the input tuned circuit has variable tuning then the RF amplifier must also have variable tuning and the two tuned circuits must be tuned in step with each other (ie they must be ganged). Ganging is achieved by mounting more than one variable capacitor on one spindle.

c. Detector (Demodulator)

Purpose - to extract the information which is being carried by the RF. This is the opposite process to modulation in the transmitter. It is known as detection or as demodulation. The most common device employed as a detector is the diode. (valve or semi-conductor type).

D. AF Amplifier

Purpose - to amplify the demodulated signal (eg an audio frequency) to enable it to drive the output device (eg a loudspeaker).

e. Loudspeaker

Purpose - to convert the AF signals into sound waves. Headphones serve exactly the same purpose but at a lower power.

NOTE: If this basic receiver was being used to receive vision instead of sound, or to receive pulses of RF (as in radar) then the last two stages would be a video frequency amplifier and a cathode ray tube instead of the AF amplifier and loudspeaker.

RECEIVER CHARACTERISTICS

54. The following characteristics are of importance in determining the suitability of a receiver for a particular task.

a. Sensitivity

The ability of a receiver to pick up a weak signal and produce a useful output. A very sensitive receiver is required to receive signals a long distance from the transmitter. In a radar system, when it is required to receive very weak echoes from small targets, a highly sensitive receiver is necessary. Gain is a term relating to the amount of amplification provided by an amplifier. When applied to a receiver, it indicates the total amount by which the received signals are amplified in the receiver. A receiver with high gain will therefore be a very sensitive receiver.

b. Selectivity

The ability of a receiver to select the desired RF signal from all the RF signals present and to reject all unwanted frequencies - even those close to the wanted frequency. Good selectivity is necessary if interference from unwanted signals is to be avoided.

c. Fidelity

The ability of a receiver to reproduce the original information, with which the transmitter was modulated, without distortion. This means in practice that speech and music will sound correct and that the square pulses used in radar systems remain square and will not be rounded off in the receiver.

d. Bandwidth

The ability of a receiver to receive a band of frequencies rather than a single frequency only. A certain bandwidth is necessary to achieve good fidelity. It seems therefore that a conflict must arise between the requirements for good selectivity which demand narrow bandwidth and good fidelity which demands wide bandwidth. This is in fact true and a compromise must be made. The bandwidth is chosen (by the designer) to give acceptable selectivity and fidelity taking into account the purpose for which the receiver is to be used.

THE SUPERHETERODYNE RECEIVER

55. Introduction

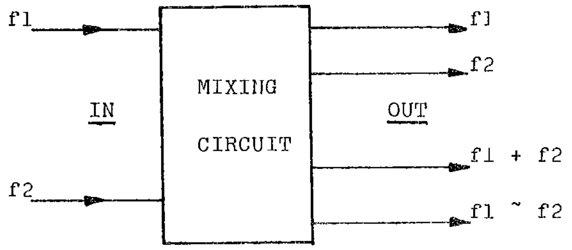
To obtain good sensitivity it is necessary to have a number of RF amplifier stages. To obtain good selectivity it is necessary to have a number of tuned stages. As each RF amplifier stage must be tuned in the same way as the input tuned circuit, it follows that the use of more RF amplifier stages will satisfy both requirements.

Unfortunately serious difficulties arise in ganging the tuning of more than three stages (including the input tuned circuit). This is a very serious handicap of the TRF receiver and for this reason this type of receiver is no longer used.

Another type of receiver, known as the Superheterodyne Receiver was therefore developed which does not suffer from the drawbacks of the TRF receiver. The superhet receiver, as it is normally called, is almost universally used today.

56. Frequency Mixing

Before considering the superhet receiver it is necessary to consider what happens when two frequencies are mixed together eg:



FREQUENCY MIXING

Figure 26

Mixing produces many frequencies (harmonics) but the important ones for our purpose are the four frequencies shown in fig 26:

a. The two original frequencies.

b. The SUM of the two originals.

c. The DIFFERENCE between the two originals.

This is ALWAYS true no matter what two frequencies are mixed. Frequency mixing is also known as HETERODYNING.

57. The Superheterodyne Principle

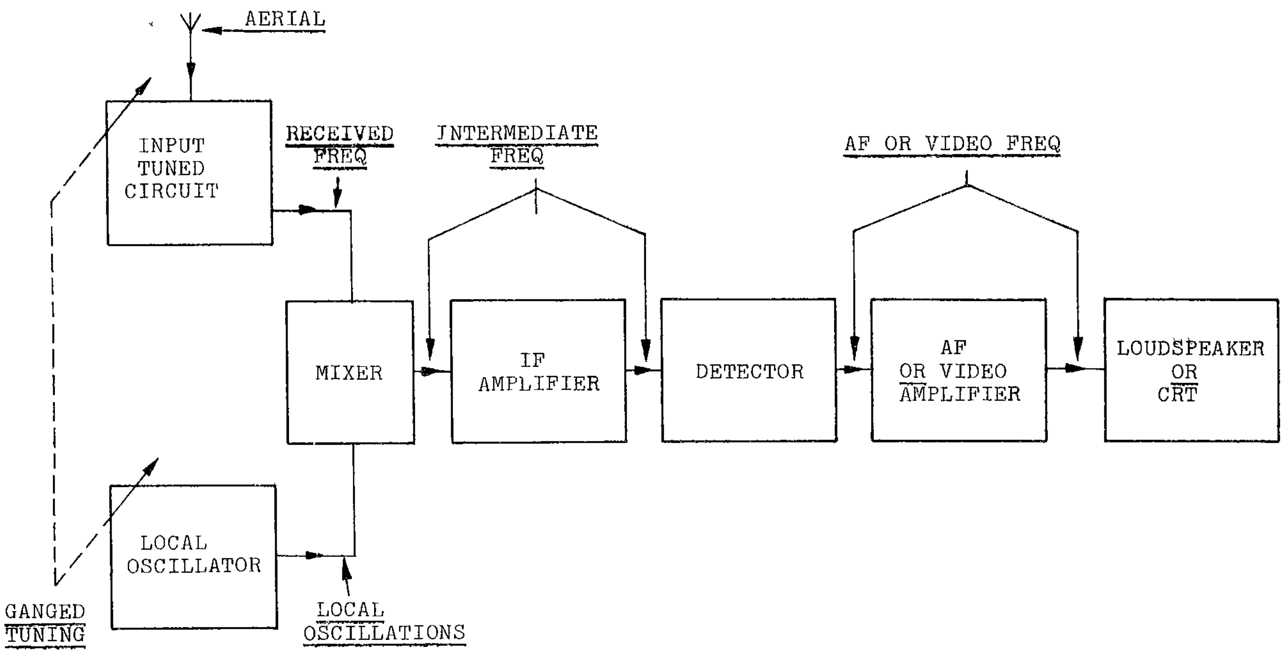
It has been seen that the problem with the TRF receiver was not the number of tuned stages required, but in ganging the tuning of a number of stages. The problem does not arise if variable (either continuously variable or in steps) tuning is not required.

If all the various frequencies received can be converted to a single radio frequency, this single RF can be amplified by a number of tuned RF amplifier stages which are all tuned to the same frequency. The important point is that the RF amplification now takes place at one fixed frequency, so that variable tuning is never required. The problem of ganging does not now arise.

It is of course necessary to convert all received frequencies to this one fixed frequency in the initial stages of the receiver. This is the principle of the superhet receiver and this is the difference between the superhet receiver and the TRF receiver.

NOTE: The term "superhet" is a shortened version of "superheterdyne" which itself is shortened from "supersonic heterodyne". Supersonic heterodyne simply means heterodyning (ie mixing) two frequencies to produce a difference frequency which is supersonic (ie above the sonic (audio) frequency band). The superhet principle therefore, means mixing two frequencies so as to produce another radio frequency.

58. The Superheterodyne Receiver



BLOCK DIAGRAM OF SUPERHET RECEIVER

Figure 27

a. Input Tuned Circuit

Purpose - same as in the TRF receiver. The output is the "received frequency", ie the frequency to which the receiver is said to be tuned. It forms one input to the mixer stage.

b. Local Oscillator

Purpose - to produce RF oscillations at a frequency which differs from the received frequency by a constant fixed amount. The local oscillator (LO) frequency must therefore be tuned exactly in step with (ie ganged to) the tuning of the input tuned circuit, but at a different frequency than the input tuned circuit. Local oscillations form the other input to the mixer stage.

c. Mixer

Purpose - to mix the received signal from the input tuned circuit with the local oscillations to produce a difference frequency. If the tuning of the input tuned circuit and the LO is corrected ganged the difference frequency produced by the mixer will always be the same. This is an ESSENTIAL requirement. The difference frequency is known as the "intermediate frequency" (IF) because it comes between the RF input stage and the AF (or video) output stages.

The choice of IF is a design problem and depends on the purpose of the receiver and the RF band it is required to work in. (eg Broadcast RX - 470 kHz; typical centimetric radar RX - 45 MHz). Any modulation present on the received RF will still be present on the IF. It can therefore be detected in the same way as if the received RF had itself been amplified. (ie as in the TRF receiver).

d. Intermediate Frequency (IF) Amplifier

Purpose - to amplify the IF sufficiently to operate the detector. A number of stages may be used to give good sensitivity and good selectivity. (eg a broadcast RX may have two stages; a typical radar RX may have six or eight stages). The IF amplifier must have sufficient bandwidth to give acceptable fidelity.

e. Detector - Audio or Video Amplifier

Loudspeaker, Headphones or CRT

Purpose - all these stages perform the same function as in the TRF receiver.

AUTOMATIC FREQUENCY CONTROL (AFC)

59. Introduction

It is often necessary to adjust the frequency of an oscillator in order to make compensation for varying circuit conditions. An AFC circuit must therefore be able to keep a check on a wanted frequency and, if that frequency starts to change, it must automatically bring it back to the desired frequency. This wanted frequency may be the direct output from an oscillator or it may be the frequency which results from the mixing of an oscillator output with another frequency. Whatever the case, AFC can be used to maintain the wanted frequency constant at the desired frequency.

60. Methods of Controlling the Frequency of an Oscillator

We know that the frequency of an oscillator is determined by the values of L and C. If either L or C can be varied, therefore, the oscillator frequency can be varied (eg manual tuning of superhet receiver by the use of a variable capacitor). It is not always practicable, however, to make constant manual adjustments to compensate for slight oscillator frequency drift.

If the frequency of an oscillator could be controlled electrically instead of mechanically (as previously described) then the process of automatic adjustment of frequency would be made much easier to achieve. A number of devices exist which permit this. One example only is given - the "varicap diode". This is a special semi-conductor diode operated with reverse bias. Under these conditions the diode acts as a capacitor and the value of capacitance is dependant on the bias voltage.

If such a device is included in the tuned circuit of an oscillator then the oscillator frequency can be controlled by use of a control voltage applied as bias to the varicap diode.

61. Production of Control Voltage

First it is necessary to know whether or not the frequency in question is correct and, if not correct, whether it is too high or too low. This is the purpose of a circuit called a "frequency discriminator" (fig 28). This circuit, which contains tuned circuits and rectifiers, produces a DC voltage which depends on the frequency of the input. If, therefore, the wanted frequency is fed to a frequency discriminator, a change of frequency will cause a change of DC voltage output. The DC voltage output can then be used as the control voltage to adjust the oscillator frequency (see fig 28). The following sequence therefore takes place automatically and continuously:

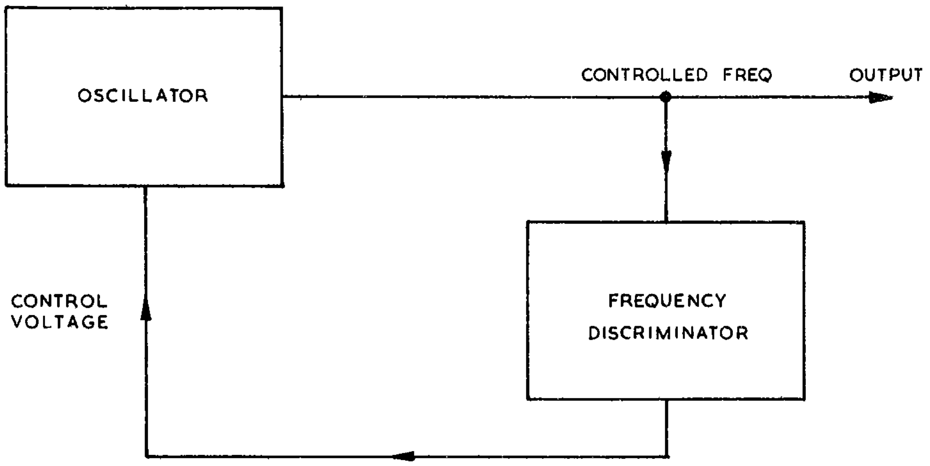
a. Desired frequency drifts slightly.

b. DC output from discriminator changes.

c. This change, fed to the oscillator, causes the oscillator frequency to change slightly (in the correct direction).

d. Desired frequency returns to correct frequency.

The system is "self correcting", any error in frequency being automatically reduced to zero. An AFC system is therefore an example of a simple "closed loop servo".



SIMPLE AFC SYSTEM

Figure 28

CENTIMETRIC RADAR RECEIVER

62. Introduction

The centimetric receiver will be considered as part of a centimetric transmitter-receiver because it is rarely encountered independantly. In this context it is normally a superhet receiver with the LO controlled by an AFC circuit. This is the type of receiver now discussed.

63. The Need for AFC

It will be remembered that a primary radar system receives the same frequency (after reflection) as it transmits and that the transmitter oscillator is usually a magnetron. It is therefore the magnetron frequency which (after refletion) becomes the received frequency and is mixed with the LO frequency in the mixer stage to produce the IF.

A magnetron oscillator is not a stable oscillator and its output frequency may drift anything up to 50MHz away from its nominal frequency. Remember that in a superhet receiver the difference between the received frequency and the LO MUST be constant. If this is to be achieved either, (1) the magnetron frequency must be stabilised or, (2) the LO frequency must be made to follow any changes in received frequency (ie Magnetron frequency). The LO in a centimetric receiver is usually a reflex klystron and it will be remembered, the frequency of a reflex klystron can easily be altered by altering the reflector voltage. The custom therefore is to control the LO frequency so as to keep its frequency a constant distance from the received frequency. It will now be apparent that an AFC circuit can be used to keep the difference frequency (ie the IF) constant.

64. Block Diagram of Centimetric Receiver

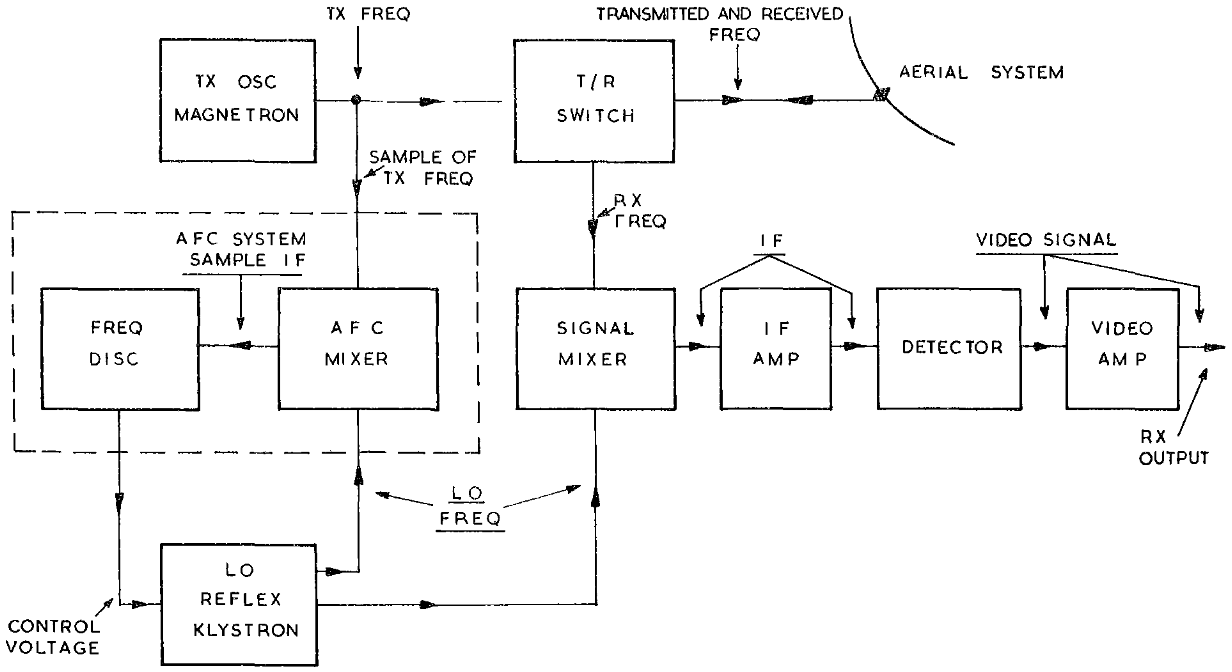


Figure 29

Refer to fig 29. The application of AFC to the centimetric receiver will now be explained. All other blocks in this diagram have been explained previously so they will not be covered again here.

The AFC system works in the following way:

a. Assume magnetron frequency drifts slightly. This will cause the IF and the Sample IF to change from the desired frequency.

b. The change in the sample IF fed to the frequency discriminator causes the control voltage output from the discriminator to change.

c. The change in control voltage fed to the LO reflector causes the LO frequency to change (ie to follow the magnetron).

d. The sample IF and therefore the IF return to the desired frequency.

NOISE IN RECEIVERS

65. Introduction

Noise is the name given to any unwanted electrical signals or disturbances which occur in any electronic equipment. In a broadcast receiver such unwanted electrical disturbances are heard as a hiss or as crackles through the loudspeaker. In a television receiver noise appears as spots or as an overall increase in background brightness on the picture tube as well as being heard through the loudspeaker. In a radar system noise may appear as "grass" on a type A display or as bright spots on a type B or on a PPI display. In every case, if the noise level becomes excessive it can completely mask the required signal whether the signal be sound or vision or radar pulses. It is clear therefore that noise should be kept to a minimum in all receivers.

66. Sources of Noise

Noise may be introduced into a receiver from the following sources:

a. External

(1) Radio Frequency Interference. This includes unwanted radio transmissions, RF interference generated by electrical equipment (eg car ignition systems; neon signs) and atmospheric disturbances like thunderstorms.

(2) Interference Introduced via Power Supplies. This includes interference from mains operated electrical equipment like electric drills or heating thermostats.

b. Internal. Small random currents are produced by all electrical components but thermionic valves are probably the worst offenders. Klystrons in particular generate a lot of noise. In any receiver, and particularly if it has high gain, any internally generated noise is amplified along with the required signals and will be present at the receiver output. Noise produced in the early stages of a receiver is subjected to more amplification than if produced in the final or output stages. Noise introduced in the early stages of a receiver is therefore particularly damaging.

67. Reduction of Noise Level

a. External Noise

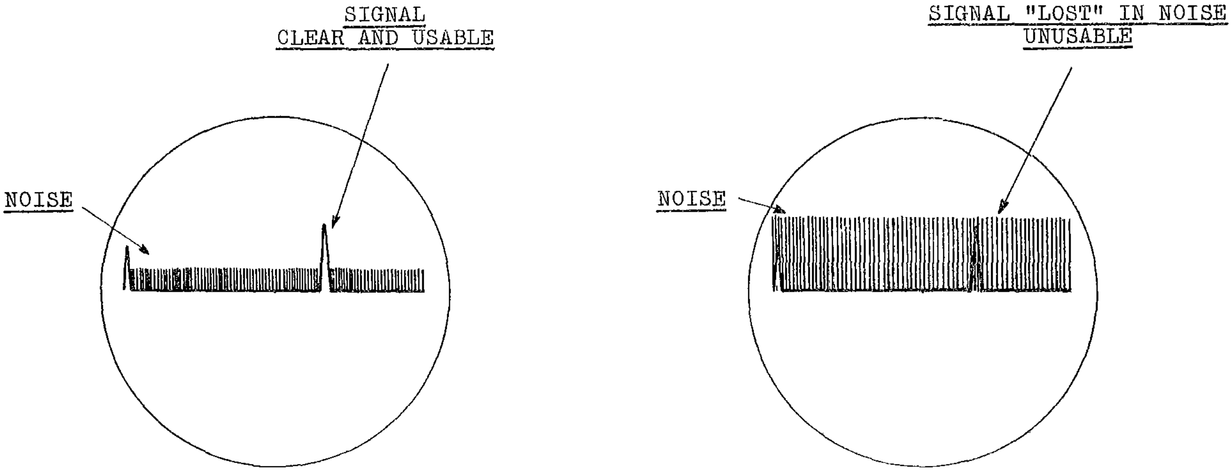
(1) RF Interference. It is impossible to eliminate this when it occurs at the same frequency as the wanted signal. The use of selective input stages and careful screening of the RF section of the receiver can reduce the amount of noise picked up. If the interference comes from a different direction than the wanted signal it can be reduced by the use of directional aerials.

(2) Introduced via Power Supplies. Can be prevented by efficient filter circuits in the equipment and by careful screening. Proper suppression of equipment which produces this type of interference is of course the real cure.

b. Internal Noise can never be completely eliminated but it can be reduced by good design and by the use of good quality components, eg a specially designed mixer stage, known as a "balanced mixer" will reduce the effect of klystron noise; a specially designed low noise amplifier known as a "casode amplifier" may be used as the first IF amplifier stage; the use of a receiver bandwidth no wider than is necessary to obtain the required fidelity will reduce the amplification of general noise.

68. Signal/Noise Ratio

Wanted signals should be as large as possible compared with the amplitude of any noise voltages. The ratio of signal level to noise level is very important. As long as signals are greater in amplitude than the noise, the signals are distinguishable from the noise and are therefore usable. If signals and noise are the same amplitude (or noise becomes greater in amplitude than the signals) the signals are indistinguishable from the noise and are therefore unusable. The signal/noise ratio of a receiver is the most important factor governing the ability of the receiver to receive weak or distant signals and produce a usable output. Signal/noise ratio should therefore be as high as possible. Figure 30 shows two examples on a type A display.



a. Good SIG/NOISE ratio

b. Poor SIG/NOISE ratio

SIGNALS AND NOISE ON TYPE A DISPLAY

Figure 30

CONTROL OF RECEIVER GAIN

69. Introduction

The term "receiver gain" refers to the gain (ie the amount of amplification) of the RF and IF stages of a receiver. It does not refer to the amplification which takes place in the audio or video frequency stages which are regarded as being separate for this purpose.

70. Methods of Controlling Receiver Gain

The gain of any amplifier depends on a number of factors one of which is the bias voltage. If therefore the bias voltage can be controlled then the gain of the amplifier can be controlled. The most common methods of controlling receiver gain are as follows:

a. Manual Gain. Generally a potentiometer with a control knob accessible to the operator. It adjusts the bias level (normally of the IF amplifiers) and therefore determines the gain of the receiver.

b. Automatic Gain Control (AGC). The purpose of this method is to maintain a constant level of receiver output even though the received signals vary in strength. The gain of the receiver (normally the IF amplifiers) is automatically increased if weak signals are received and decreased if strong signals are received. This is done by the AGC circuit in the receiver which rectifies the signals and produces a DC voltage which is then used to control the bias level of the RF or IF stages. Strong signals produce bias which reduces receiver gain whilst weak signals produce bias which increases receiver gain. The output signal strength therefore remains fairly constant. AGC is used in all radio and television receivers and in some (though not all) radar receivers.

c. Swept Gain. Swept gain is used in some primary search radars to reduce clutter on the display from close range echoes (eg ground returns; heavy rain etc). It may also be used for other purposes in some radar systems. It works as follows: a specially generated waveform is fed to the IF amplifiers. This waveform adjusts the bias level so as to reduce receiver gain at close range (where signals are usually strongest) and then gradually increases the gain until the normal pre-set level is reached at some pre-determined range. Signals from longer ranges (which are usually weaker) therefore receive more amplification than those from close range. The range at which gain is returned to "normal" depends on the requirements of the radar system concerned.

Swept gain therefore relates receiver gain to the range from which signals are received. Any signal (weak or strong) gets the same amount of amplification if received at the same range.

71. Control of Gain in Audio and Video Stages

a. Audio Stages. The gain of these stages is normally fixed but the amplitude of signal applied to these stages (from the detector) is normally variable by the use of a potentiometer, thus allowing the sound output level to be varied. Such a control is known as a "volume control".

b. Video Stages. In some equipment there may be control of the output from the video stages which is independant of the receiver gain control. The methods of achieving this are varied. A control which gives this facility is usually termed a "contrast control".

RECEIVER SUPPRESSION AND GATING

72. Suppression

When a high power radar transmitter operates, some energy finds its way into the receiver. Compared with normal received signal, such transmitter breakthrough, as it is called, appears as a very strong signal. It can be strong enough to overload the receiver, so preventing it from being able to receive the comparatively weak return signals for a period of time after the transmitter pulse ends. This prevents signals being received from close ranges. This blocking of the receiver by transmitter breakthrough is called receiver paralysis.

Receiver paralysis can be prevented by applying a pulse, coincident with the transmitter pulse, to the receiver to cut the receiver OFF for the duration of the transmitter pulse. Such a pulse is normally generated in the modulator stage of the transmitter and is applied to the IF stages in the receiver. It is known as a suppression pulse and the process is known as receiver suppression.

Suppression pulses from another radar system may also be applied to a receiver to prevent the receiver being affected by the other radar transmitter (eg, another radar in the same aircraft). It follows, therefore, that most radar transmitters have provision to feed suppression pulses out to other radar systems.

73. Receiver Gating

In most pulsed radar systems designed to measure range, there is a certain amount of time between the end of the timebase (ie, Maximum Range) and the start of the next timebase (ie, the next transmitter pulse). During this waiting time, signals and noise may still be received and, of course, internal noise is also being produced. The radar system cannot make use of any receiver output during this period of time, in fact, any such output can be detrimental to the operation of the radar, eg, in some radar systems the receiver output is fed to computing circuits or to automatic tracking systems. If unwanted signals (as described above) or excessive noise is fed to such circuits, it can result in inaccurate measurements or unreliable operation of these circuits.

A waveform is therefore generated which is fed to the receiver to cut the receiver ON for the required period of time (ie, from zero range to maximum range) and to cut the receiver OFF at all other times (ie, during the waiting period between maximum range and the next transmitter pulse).

This process is known as 'receiver gating'. The gating waveform may be fed to the IF stages or to the video stages of the receiver.

The receivers of some radar systems may be gated for reasons other than that described here. These other uses of receiver gating depend on the requirements of the radar systems in which they are used.