NRC Publications Archive
Archives des publications du CNRC

An elementary introduction to R.D.F.

Campbell, R. G.

For the publisher's version, please access the DOI link below./ Pour consulter la version de l'éditeur, utilisez le lien DOI ci-dessous.

https://doi.org/10.4224/40003961

NRC Publications Archive Record / Notice des Archives des publications du CNRC :
https://nrc-publications.canada.ca/eng/view/object/?id=1ca15bba-8f95-4bb7-90bb-befaf7fcb893
https://publications-cnrc.canada.ca/fra/voir/objet/?id=1ca15bba-8f95-4bb7-90bb-befaf7fcb893

Access and use of this website and the material on it are subject to the Terms and Conditions set forth at
https://nrc-publications.canada.ca/eng/copyright
READ THESE TERMS AND CONDITIONS CAREFULLY BEFORE USING THIS WEBSITE.

L'accès à ce site Web et l'utilisation de son contenu sont assujettis aux conditions présentées dans le site
https://publications-cnrc.canada.ca/fra/droits
LISEZ CES CONDITIONS ATTENTIVEMENT AVANT D'UTILISER CE SITE WEB.

Questions? Contact the NRC Publications Archive team at PublicationsArchive-ArchivesPublications@nrc-cnrc.gc.ca. If you wish to email the authors directly, please see the first page of the publication for their contact information.

Vous avez des questions? Nous pouvons vous aider. Pour communiquer directement avec un auteur, consultez la première page de la revue dans laquelle son article a été publié afin de trouver ses coordonnées. Si vous n'arrivez pas à les repérer, communiquez avec nous à PublicationsArchive-ArchivesPublications@nrc-cnrc.gc.ca.

National Research Council Canada
Conseil national de recherches Canada

PRA-14

ELEC. ENG.

Declassified to
OPEN

SECRET
Copy No. 20

Rec 16/6/41

AN ELEMENTARY INTRODUCTION
TO
R. D. F.

NATIONAL RESEARCH COUNCIL
OTTAWA, CANADA

JUNE, 1941

Declassified to
OPEN

SECRET

Copy No.____

ANALYZED

AN ELEMENTARY INTRODUCTION
TO
R. D. F.

NATIONAL RESEARCH COUNCIL
OTTAWA, CANADA

JUNE, 1941

CONTENTS

INTRODUCTION

By R.D.F. we mean using Radio Waves (electromagnetic waves is a more correct name for them) to find the position of an object, or to prove that an object really exists. The object may be an airplane, a ship or even a mountain. We probably cannot see the object with our eyes, and the purpose of R.D.F. is to allow us to "see" by radio, no matter whether it is day or night, good weather or bad.

In the early days of radio great difficulty was experienced in explaining why radio waves travel so far around the earth instead of flying off into space. Another effect was noticed, and could not be explained: the fact that a station might be heard at a distance of say 100 miles: not be heard at all between 100 and 300 miles from the transmitter: and might be heard again beyond the 300 mile point - these figures are purely for example. The theory that part of the wave travelled along the earth's surface accounted for the 100 mile reception, but it was found that this wave rapidly died out, and rarely travelled more than 100 miles. How then did the wave get to the point 300 miles away?

Kennelly in the United States and Heaviside in England suggested at about the same time that there might be an electrically conducting layer in the atmosphere which reflected, or bent, the radio waves down towards the earth. In 1925 the existence of such a layer was proved, and in 1927 it was found that in reality there were two such layers, one at an average of 70 miles, the other at 170 miles.

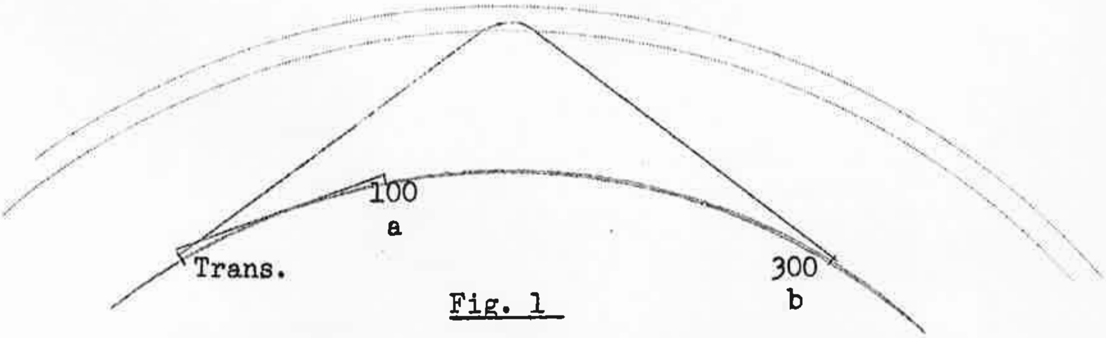


Fig. 1

Figure 1 shows the ground wave and the reflected sky wave. Point a receives the signal by means of the ground wave; point b receives the sky wave; no signal is heard between points a and b.

What has all this to do with our subject? Just this: the technique developed to prove the existence of these layers was the basis for all R.D.F. work. You see, if radio waves can be reflected, then instead of the layers in the air surely other objects too can reflect them. The reflections would give an indication of the object's existence and position - a small mirror a mile away might be invisible to our eyes, but if we were to swing a beam of light around until it landed on the mirror the reflection would at once betray the mirror's position. See Figure 2.

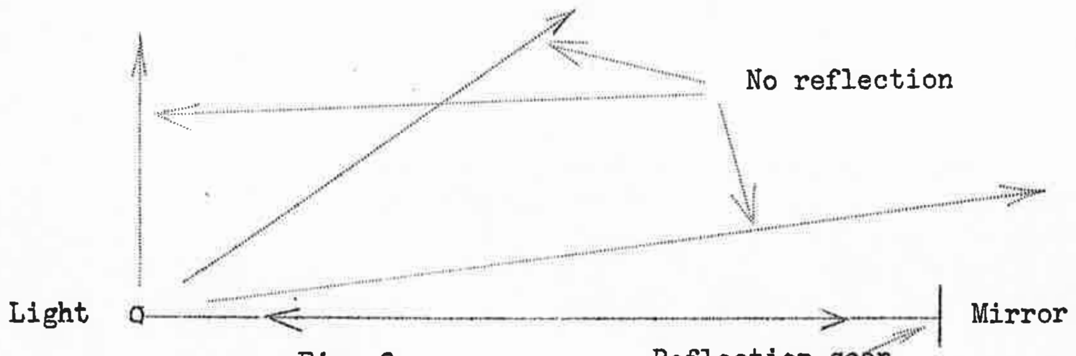


Fig. 2

Of course it is not so simple as this would suggest when we are dealing with the reflection of radio waves, but by suitable apparatus a similar result can be obtained.

This article then will attempt to deal with the problem of how the reflection of radio waves can be used to determine the position of an object.

THE PROBLEM

Our first step in finding the position of an object is to decide just what must be measured to find that position - having decided what is to be measured we will later see how to do it.

First, let us consider an object on the earth's surface. We will imagine the earth to be flat.

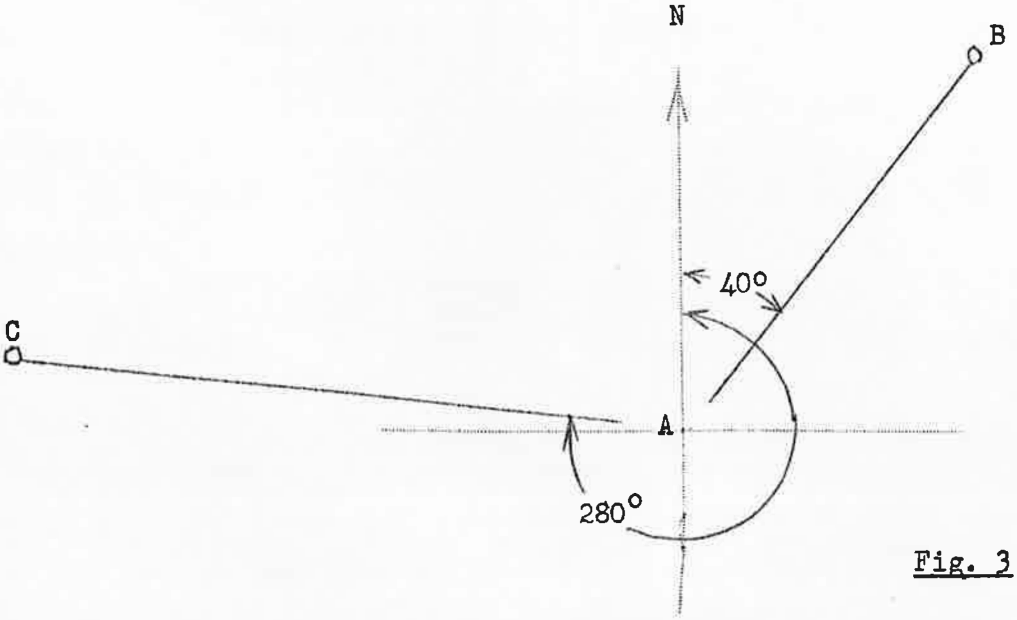


Fig. 3

We are, in Figure 3, looking down on the earth from an airplane; however, let us imagine that a person at position "A" wants to locate an object "B". Maybe he wants to point a gun at B and since it is dark he cannot see B. What will he have to know? "A" will need to know two things probably - the distance to "B" and in what direction from him "B" is. Suppose we mark the points of the compass on our diagram then we see that "B" is nearly northeast of "A". This would do as an indication of the direction but is it accurate enough? Since a circle can be divided into 360 degrees, let us mark our compass into 360 parts, starting at N. and going around in the same direction as the hands of a clock. Now we see that the line from "A" to "B" really is at the 40 degree mark - this is much more accurate. This angle - around from the north - is called the bearing or azimuth of the object "B" and tells us where to look for it. Similarly point "C" has an azimuth, from "A", of 280°. We see that in R.D.F. work we must determine the azimuth of an object.

Sometimes we will want to know the distance from A to B. Maybe we want to set the fuse on a shell so that it will explode when it reaches "B". This distance is called the "Range" of the object "B".

Now let us start again. Suppose "B" is not on the earth's surface - maybe it is an airplane. Look at Figure 4.

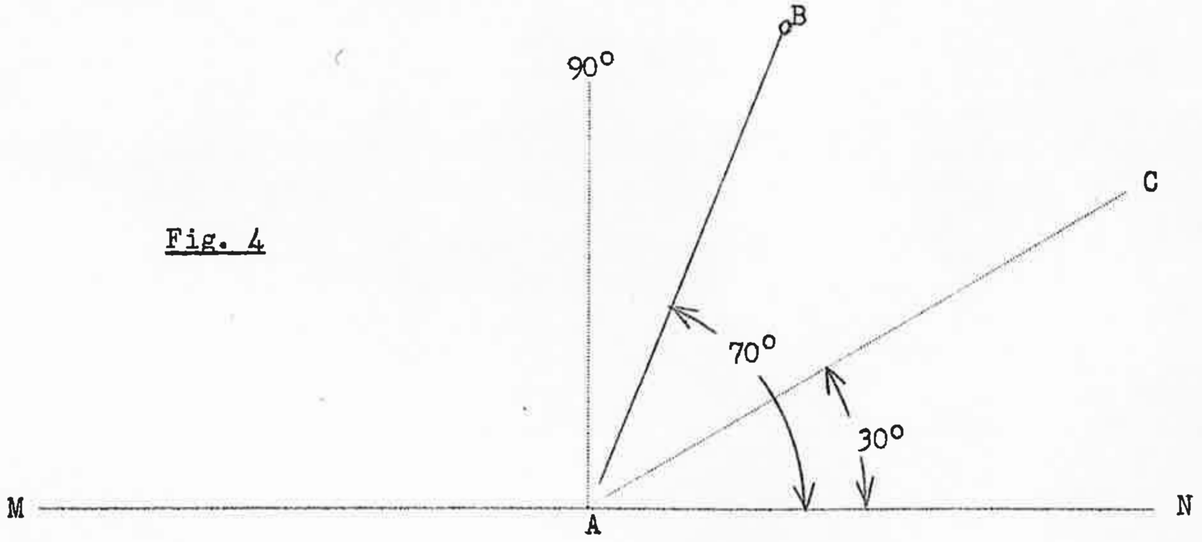


Fig. 4

Suppose MN represents the earth's surface. We are off to one side looking at the earth. A person at "A" wants to locate an object "B" up in the air. If he could see it he would have to bend his head back and look up. The line AB makes an angle with the earth's surface - in the diagram its about 70°. This angle is called the angle of elevation of the object. Point "C" has an elevation angle of 30°. Would the angle of elevation alone enable us to locate "B"? No, since while it would tell us how far back to tilt our head we would still have to turn around a circle to find in what compass direction "B" was from us.

Thus we need both azimuth and elevation angles to find the location of an object if the object is off the earth's surface - and probably the distance or range AB as well.

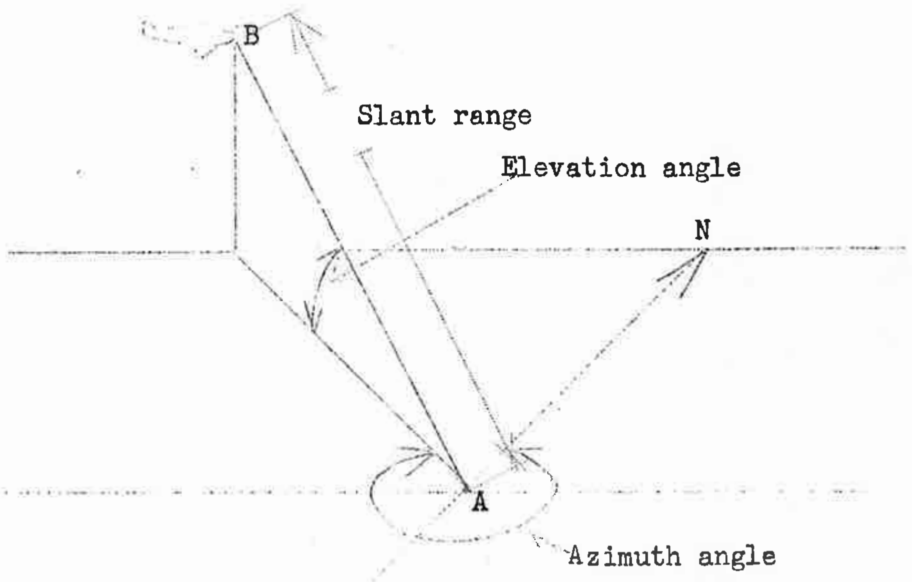


Fig. 5

Figure 5 is an attempt to show us all three things in one diagram, Range, Elevation angle and Azimuth. These three things will definitely fix the location of "B" from us - as accurately as we need. Any radio apparatus that is to find "direction" of things on the earth must measure azimuth and may be range. Any radio apparatus that is to find the direction of things above the earth's surface must measure azimuth and elevation and maybe range. You should have the meaning of azimuth, elevation and range clearly in mind before reading further.

RANGE

On the west coast of Canada when the weather is foggy the ship's captain blows a sharp toot on his whistle, notes the time, listens for the echo to return, and notes the time again. He knows that sound travels at approximately 1000 feet per second so he divides the time by two, since the sound goes to shore and back, and calculates his distance from shore. For example, suppose the echo returns in 6 seconds - then he knows he is 3 x 1000 = 3000 feet from shore. Please note, however, that the "toot" must be short, or else he won't be able to hear the echo, because the whistle would deafen him.

We have already noted that radio waves can be reflected. It would be a simple matter to determine the range of an object by timing the reflected wave (or echo) just as the steamboat captain did: however, there is a catch in it - radio waves travel at 186,000 miles per second, not 1000 feet per second. This means that if the range was 10 miles, the radio wave would make the round trip in about 1/10000 of a second! The difficulty then is how to time this extremely short interval - it can be done and we will see how later. Also the length of the pulse or "toot" of radio waves must have a sharp beginning and end: that is, the voltage must increase and decrease quickly.

AZIMUTH AND ELEVATION - Directional Antennas

We shall now consider the problem of the measurement of azimuth and elevation.

When we speak of radio waves we at once think of the more familiar waves on water. This is not actually correct as radio waves are much more complex; however, this idea will do for our purposes.

Suppose we have a smooth-surfaced pool of water and we drop a pebble in at its centre. A circle of ripples spreads out in all directions - an ordinary aerial sends out radio waves in this fashion, just as an ordinary receiving aerial collects waves from any direction.

Certain forms of aerials have the property of sending radio waves in certain directions only, much like the beam of a searchlight: these same aerials can only receive when the received waves come along a narrow beam. Such aerial arrays are called directional antennas: see later in this article.

We can do three things then to measure angles.

(1) We can transmit in all directions and turn a directional receiving aerial until the echo is received.

(2) We can receive in all directions and turn our sending aerial until an echo is received.

(3) We can, for greatest accuracy turn both our sending and receiving directional antennas until an echo is received.

For all these cases we can mark the number of degrees on our rotating directional antenna, starting with zero when the beam is going North around to 360° for the azimuth; starting at zero when the beam is horizontal up to 90° when the beam is overhead, for the elevation angle.

The accuracy of course will depend on the narrowness of the beam - the narrower the better. Accuracy also will depend on the design of the receiving equipment. We will discuss these two factors later. Methods (1) and (3) are by far the most commonly used.

SENDING

As was mentioned in the section on Range the duration of the pulse sent out must be extremely short - about 1 millionth of a second (1 micro-second) is commonly used. This is so that there will be a sharp and definite pulse sent out, with a definite beginning and ending. The switching is accomplished electrically and usually the sender is turned on for 1 micro-second, then off then on again, about 1000 times a second (recurrence frequency = 1000). Even though these times are short, we have seen that this allows plenty of time for the wave to travel from the sender to the object and back to the receiver before another pulse is sent out.

Actually if the object was not moving one pulse of radio waves could be sent out, be reflected from the object and from the received echo we might be able to measure the range, azimuth and elevation of the object. However, even with this fixed object, it is more accurate to repeat the pulses and measurements over and over. In the case of a moving object we must obtain our information over and over so that the positions of the object may be determined continually, and regularly. Metal parts of objects give most of the reflections.

The power output of the sender may be anything from 1 KW - 100 KW or more depending on the range desired. The wavelength of the sender may be anything from 20 metres down to 10 cm. There is a definite relationship between best wavelength and size of object - the best result as far as size of echo is concerned is obtained with a wavelength twice size of the reflecting parts of the object. While this is the best wavelength, another factor comes in. The importance of the narrowness of the beam has been mentioned - and in general the beam is much narrower on the shorter wavelengths. Since this is of greater importance than size of echo (we can use greater power in the sender or more amplification in the receiver to increase size of received echo), the shorter waves are used. Wavelengths of 10 cm. are being used to-day.

Since the wavelengths are short we find special tubes being used in the senders. New types such as magnetrons may be employed, resulting in greatly reduced physical size. The high frequencies used, while they complicate problems of insulation and capacity, do result in simplification in design; numbers and sizes of components are reduced. Due to directional beams and short pulses the apparent power output is largely increased resulting in greatly increased efficiency.

RECEIVER

Radio waves of course may be of any frequency up to millions of cycles per second. However, they may be considered as being split up into audio frequency waves up to approximately 25,000 cycles, and radio frequency waves from there to 3,000 million cycles and beyond.

The audio frequency waves which are those corresponding to ordinary sound cannot be radiated satisfactorily and the radio frequency cannot be heard though they can be radiated through space. To replace the wire which is necessary to carry audio frequency the radio frequency wave is modulated, that is, its amplitude or size is made to vary with the amplitude of the audio frequency. The R.F. so used is called a carrier wave.

The job of the receiver is to remove the R.F. and leave the A.F. behind. An R.D.F. pulse looks like Figure 6.

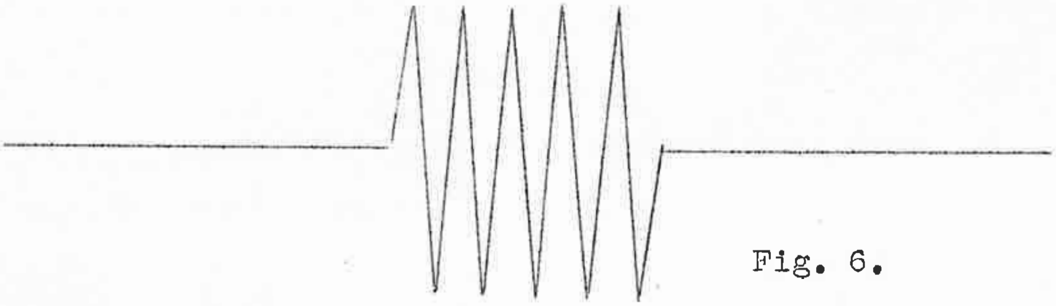


Fig. 6.

Since the frequency is so high it is not easy to amplify R.F. signals. The job would be much simpler if the speed of vibration was less.

It is well known that if two tuning forks have nearly the same frequency beats result of frequency equal to the difference of the two fork frequencies. In a similar manner two R.F. waves can be caused to beat, the beat frequency being called the intermediate frequency of the receiver or I.F. One of the two beating frequencies is the received signal, the other is supplied by a small oscillator called the local or beat oscillator. The intermediate frequency can be adjusted by varying the frequency of the beat oscillator. The advantage of using an I.F. is that it is easier to handle this lower frequency in the amplifier.

A tube or crystal acts to mix these two frequencies and is called the mixer or first detector. In the usual receiver several stages of amplification of the intermediate frequency are used followed by the detector which is usually a diode. The diode removes the R.F. and leaves the A.F. behind.

Following the detector is a wide band audio frequency amplifier. This is usually called a video amplifier when the band of frequencies it can pass is extremely wide. The band of frequencies must be wide since the front of the R.F. pulse consists of many harmonics, (by harmonics we mean frequencies of 2, 3, 4 .... times the original frequency). If the harmonics are to pass through the receiver then the whole receiver must be designed to pass these frequencies. (See Figure 7.)

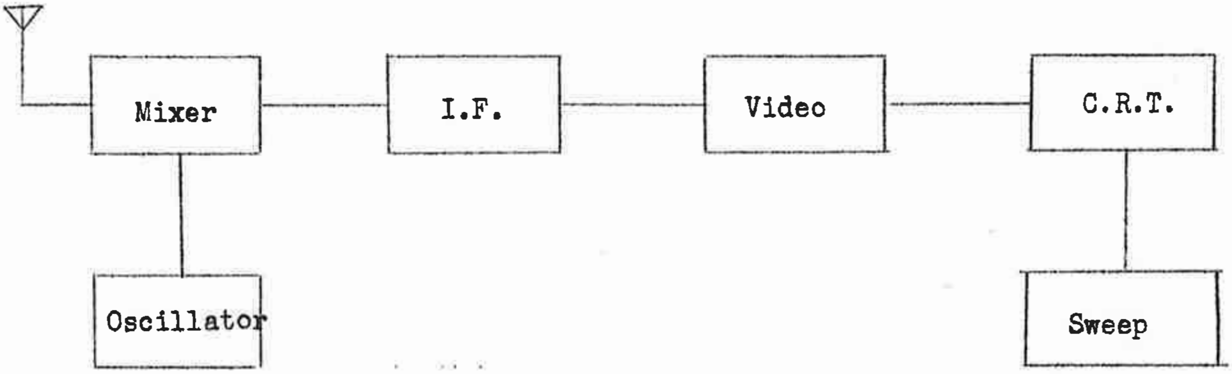


Fig. 7

The received signal is then viewed on the cathode ray tube.

CATHODE RAY TUBES

Description

Matter is made up of molecules and the molecules are made up of atoms. The atoms are considered to be constructed of a central positive nucleus with many electrons revolving around it. These electrons are small negative particles of electricity. If a metallic substance is heated some of these electrons fly off into space - an ordinary electric light bulb contains a cloud of these electrons around the filament.

If a filament is enclosed in a glass vessel and heated by an electric current, electrons will be given off. Since by the electrical laws like charges repel and unlike charges attract, if a metal plate is enclosed in the glass vessel and given a positive charge, it will attract the electrons from the filament. If the charge on the metal plate is sufficient, and if the metal plate has a hole in it, the electrons will be moving so fast they will pass through the hole and continue on beyond the metal plate. If the glass on the end of the tube is painted on the inside with some chemical like zinc silicate it will light up when the beam of electrons that have gone through the hole in the plate hits it, producing a spot of light due to fluorescence. This fluorescent effect may be made to last several seconds after the beam has hit the chemical.

In a cathode ray tube, there may be more of these metal plates, often there are three, all charged positively. These cause the electron beam to have a large velocity and also compress the beam into a small diameter to make the spot extremely sharp. The central one of these three plates is usually intermediate in voltage between the first and third and its voltage is variable to compress or expand the diameter of the beam. Thus it is called the focussing electrode.

Near the filament, or cathode, is found another metal plate with a hole in it called the grid. This, if it is made negative, will prevent the passage of the electrons from the filament or, if made neutral or very slightly positive, will allow the passage of electrons. The voltage on the grid is variable and hence the intensity of the beam can be controlled to any degree. Since the grid is extremely close to the filament and the positive plates or accelerating anodes are further away a relatively small voltage on the grid can control the beam. This really gives amplification. (See Figure 8 for the locations of these parts of the cathode ray tube.)

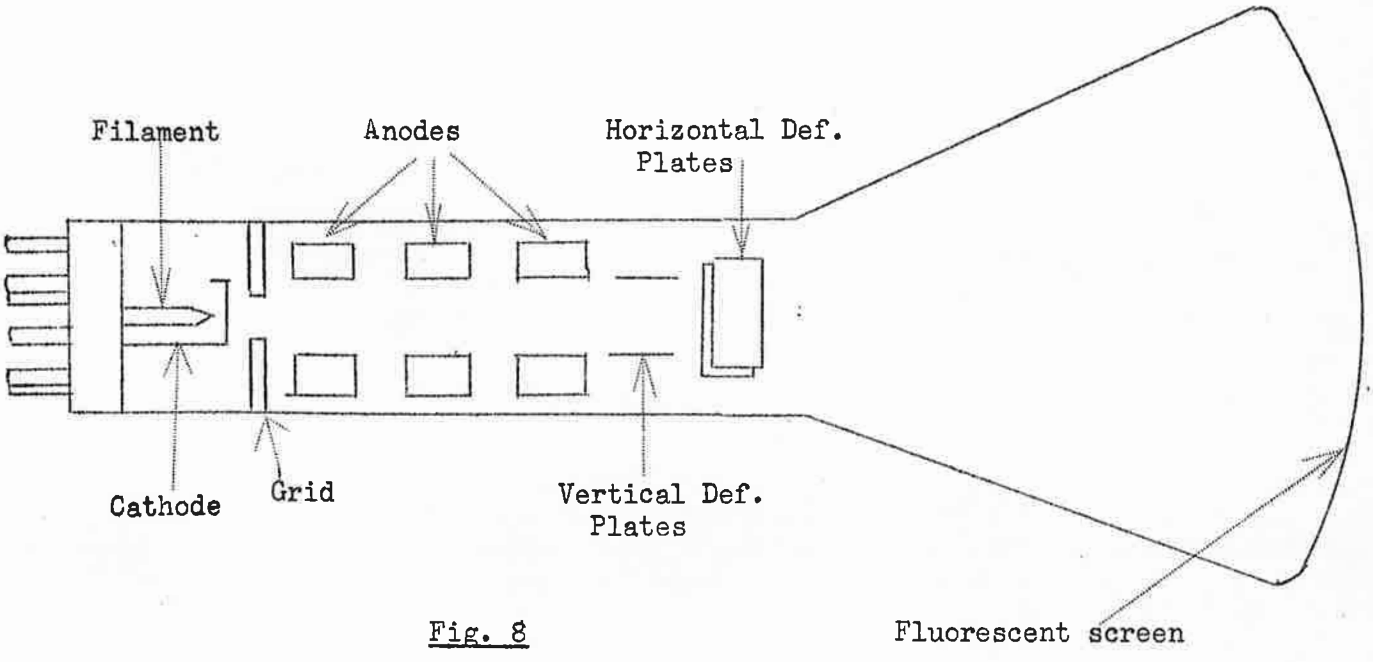


Fig. 8

The Use of the Cathode Ray Tube

The electron stream is like the current in a wire and therefore can be affected by both magnetic and electrostatic forces. If a magnet is brought near the wire a force is developed if the wire is carrying current. The electron stream corresponds to the wire and as nothing is holding it if a magnet is brought near the wire the spot on the screen will move. This can be easily demonstrated with a magnet.

If positive or negative charges of electricity or voltage are brought near the stream of electrons, the spot will also be deflected according to the law that like charges repel, unlike charges attract. Most cathode ray tubes have plates built into them near the outer end for this electrostatic (voltage) deflection. However, we can use either magnetic or electrostatic means for deflecting the beam.

In any measurement we must have some level or basis for our measurements. In the case of altitude,- sea level is used at this basis. In the cathode ray tube, we obtain our base or reference level by moving the electron beam across the tube at a constant speed or uniform velocity. The resulting picture looks like a line on the tube and is called a sweep. A cathode ray sweep then is the moving of a spot across the screen at a constant speed, that is, its motion is linear with time, the speed depending on the work we are trying to do. We can determine the time it takes the spot to cross the screen and therefore can use the cathode ray tube as a timing device.

Suppose we apply a positive voltage on the horizontal plates of a cathode ray tube (see Figure 9.)

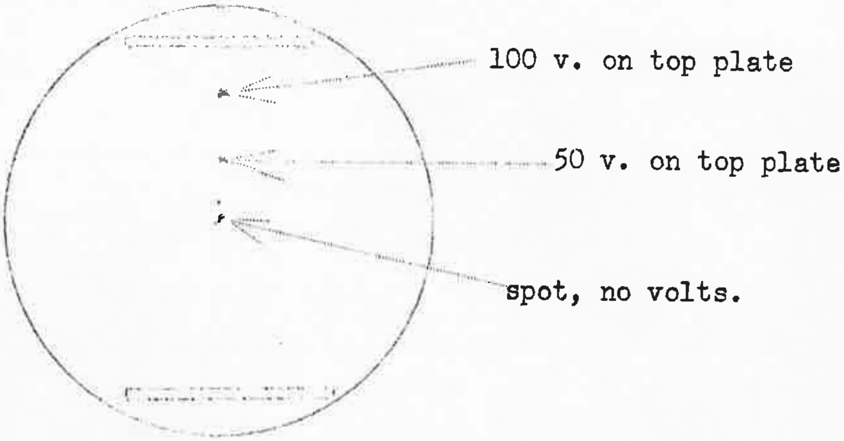


Fig. 9

If the voltage is plus on the top plate the spot will move upwards, the amount of deflection being dependent on the magnitude of the voltage, or, if the voltage is negative, the spot will move down. Thus we can calibrate the movement of the spot with voltage and so use the cathode ray tube as a voltmeter. Of course no sweep was used in this application of the tube.

An alternating current may be illustrated as in Figure 10.

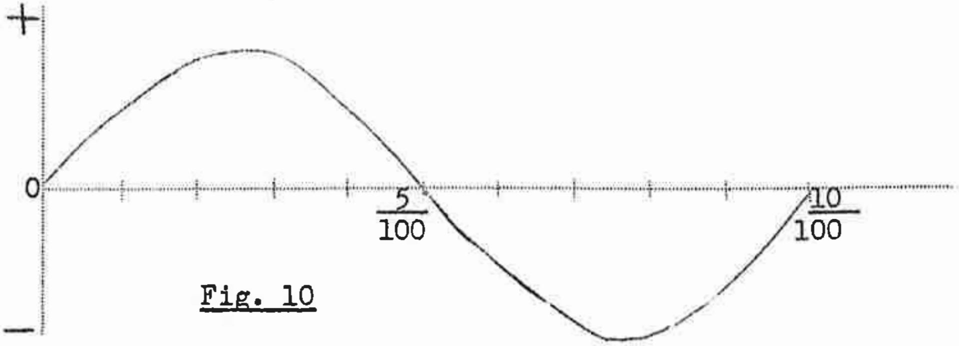


Fig. 10

When we go above the line the voltage is plus, and when we go below the line the voltage is minus. Distances along the horizontal represent time. We see then that at zero time we have zero voltage. At 2½/100 of a second after the start the voltage is at a maximum, at 5/100 of a second it is zero; at 7½/100 of a second it is at a negative maximum and at 10/100 of a second it is again zero. Fig. 10 represents a ten cycle alternating voltage.

Now suppose this alternating voltage is applied to a horizontal plate of a cathode ray tube with no sweep, that is, no voltage applied to the vertical plates. At the start the spot will be in the centre since there is no voltage, at 2½/100 of a second later the spot will be farthest up the tube; at 5/100 of a second it will be back at zero at the centre; at 7½/100 of a second it will be farthest down since the voltage is at a negative maximum; at 10/100 of a second it will be back at zero again. The result will be a vertical line on the tube. (See Figure 11.)

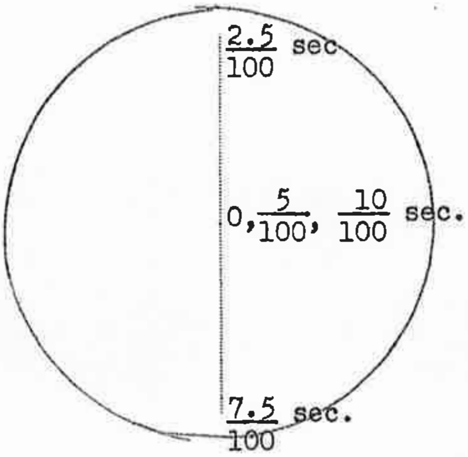


Fig. 11

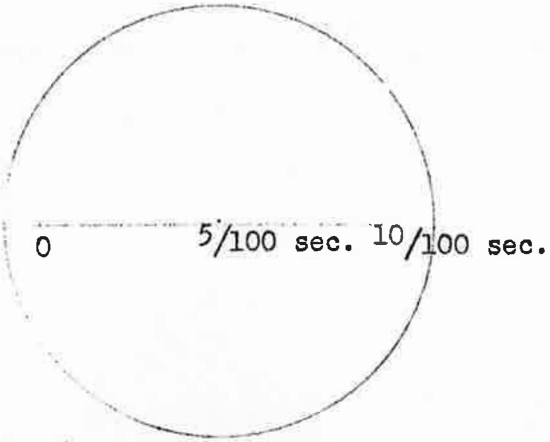


Fig. 12

In Figure 12 we see the movement that the spot will have if a steadily increasing positive voltage were applied on the right hand vertical deflection plate of the cathode ray tube. At 0 the spot would be at the left; at 5/100 of a second later suppose it is at the centre and at 10/100 of a second suppose it is at the right hand edge of the tube.

Now suppose we apply the alternating voltage to the top horizontal plate and the sweep voltage (the increasing positive voltage) to the right hand vertical deflection plate. What will happen now? At 0 the spot will be at the left since there is no voltage on either plate; $2\frac{1}{2}/100$ of a second late the spot would have been $\frac{1}{4}$ the way across but we have applied a positive voltage to the top horizontal plate so the spot will be attracted upwards from where it would have been. At 5/100 of a second the spot will be at the centre since there is no voltage on the horizontal plate. At the $7\frac{1}{2}/100$ position the spot will be down the tube since it has been repelled there by the negative voltage on the horizontal plate. At 10/100 of a second, it will be over at the right at the central line since again there is no voltage on the horizontal plate. The result of all this is a picture of the actual A.C. wave on the face of the tube. (See Figure 13.)

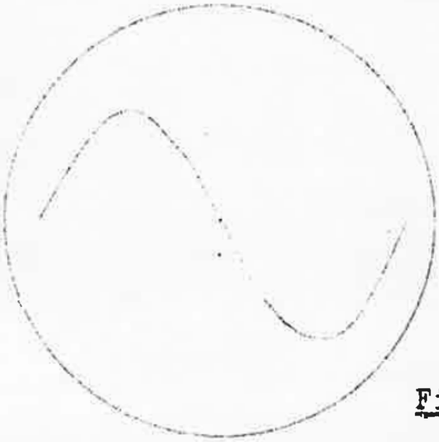


Fig. 13

Suppose the spot had moved horizontally at a slower speed then it would not have been so far across the tube when the different voltages were applied to it and we might have a picture like Figure 14.

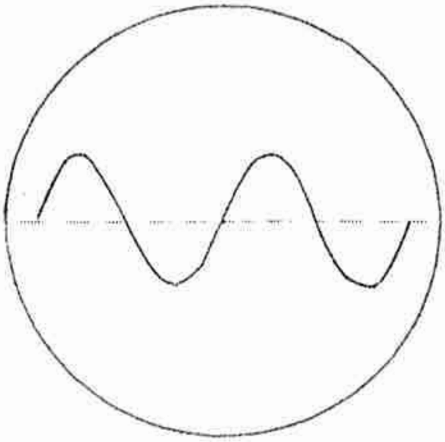


Fig. 14

In R.D.F. work we use C.R.T. (C.R.T. means cathode ray tube in the rest of this article), in place of listening to the returning echoes, that is, we place the signal from the receiver on the horizontal plates of the C.R.T. and use a sweep of a suitable length; the time of the sweep is determined by the length of time it takes the radio signal to travel from our position to the farthest distant object whose range it is desired to measure. This means that the spot must travel from the origin to the centre of the tube in the same length of time it takes the echo to return after reflection by the object, if we desire the echo to appear at the centre of the tube. Since the time of travel for the spot can be calculated, we thus have a means of timing the round trip of the pulse and so obtaining the range.

A less accurate method of determining range is not to calculate the time but to use a shorter sweep and to note the position of the echo on the sweep, the farther the echo appears from the origin, the greater the range must have been. Thus, these distances can be calibrated perhaps by using a fixed target, and the range is determined directly by a scale on the tube. (See Figure 15.)

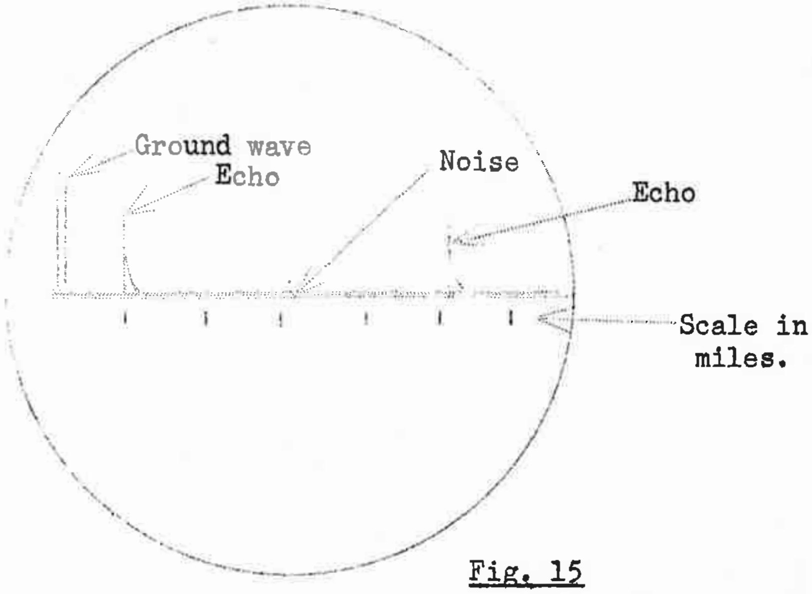


Fig. 15

You will notice a pulse near the origin at the left. This is a pulse that has travelled directly from the transmitter to the receiver and is ignored when using the apparatus.

In measurement of azimuth and elevation, the receiving aerial is turned until a received echo is at its greatest size, and the angles read from a scale on the aerials. A more accurate method is to use two aerials and put the received echo from each on the same cathode ray tube. The operator will then turn the aerials until the echoes are the same size, and they will read the angles.

Another method of measuring angles, is to have two aerial systems, put the signals into coils, rotate another coil in their fields until minimum signal is received, then read the angle. This is called the Goniometer method.

In speaking of azimuth angle, we said it was measured from zero to 360° starting at the north. However, any compass direction could be taken for zero as long as the person to whom we are giving the information knows where this zero is.

Power supplies for C.R.Ts. need supply only a small amount of current; the current may be as small as 2 milliamperes, the voltages vary from 500 to 10,000 volts for the plates while usually alternating current is used on the filaments.

Since the electron beam can be deflected magnetically the earth's magnetic field must be kept away from the tube. This means the tube must be shielded carefully.

The fluorescent screens may have a persistence of anything from 1/1000 of a second depending on their use. Zinc silicate is most usually used and gives a greenish coloured picture. Long persistence screens may cause a blurring of the image when the spot movement is slow. For high speed operation a long persistence screen is needed. Since the sweep must cross the tube and return, we must eliminate this return sweep.

The advantages of the use of C.R.Ts. in our work are:

1. The eye can judge size more accurately than the ear.

2. The echoes can be picked out of the picture that results from static.

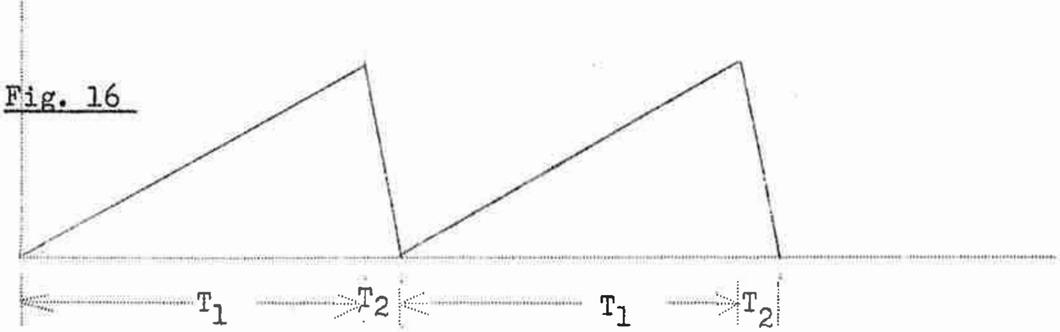
3. Range can be determined directly by a scale on the tube.

4. A C.R.T. is an indicating device whose moving parts - the electron beam - have no inertia and hence move rapidly and easily.

SWEEPS

Since we are to determine range by the relative displacement of the echo from the origin, we must make sure that the sweep is linear, that is, that its motion is uniform with time. It is desirable in order to eliminate the back-stroke, to have the sweep voltage vary with time as shown in Figure 16.

Fig. 16



T_1 represents the sweep time, and T_2 the back-stroke time. If T_1 divided by T_2 is greater than 25 or 30 the back-stroke will be so rapid as to be practically eliminated. Such an arrangement of voltage with time is called a "saw-tooth" voltage.

The voltage on the condenser, in a circuit containing a resistance, with respect to time is given by the equation:

$$e_1 = E_m(1-e^{\frac{-t}{rc}})$$

where e_1 = voltage at a time t. E_m = maximum voltage. r = resistance. c = capacity.

The curve of charging of the condenser is shown in Figure 17.

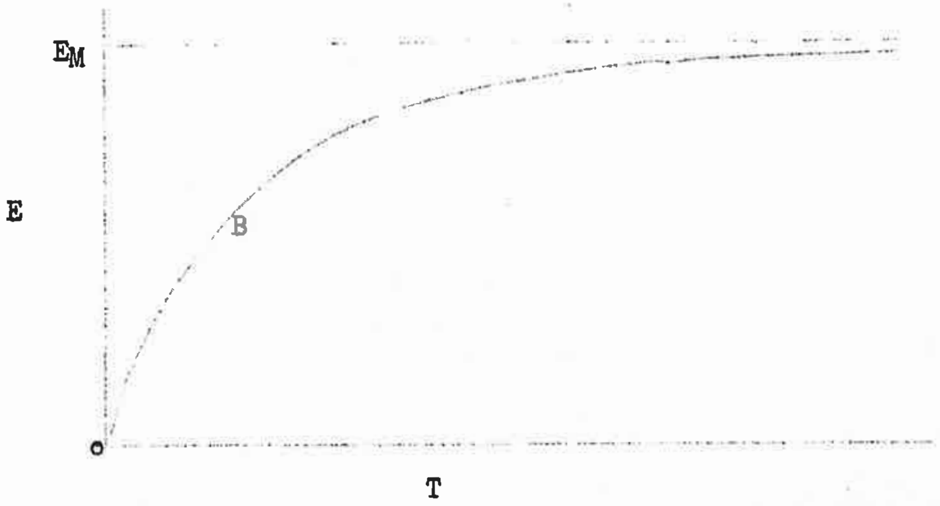


Fig. 17

Suppose we arrange a circuit as shown in Figure 18.

Fig. 18

The condenser C can be short-circuited by a switch. If the switch is closed, the condenser is short-circuited, and if it is open, the condenser can charge according to the above law, as shown in Figure 17. If the switch is closed, points 1 and 2 are at the same potential, and the spot would be at the centre of the C.R.T. Now if the switch is suddenly opened, point 1 becomes steadily more positive than point 2 as the condenser charges, and the spot would be drawn across the tube from right to left, its speed would follow the curve of Figure 17. Since this would not give a linear motion, let us confine the operation to the portion OB of the curve, which is practically straight. Linearity could also be obtained by substituting an impedance instead of the resistance R.

The switch can be a gas discharge tube, which when it is conducting, short-circuits the condenser and when not conducting allows the condenser to charge. If the condenser is charging, then when point 1 reaches the ionization potential of the tube, it suddenly starts to conduct and short-circuits the condenser. The condenser discharges suddenly giving us the return sweep in a short interval of time as shown by T_2 in Figure 16. Thus we obtain the saw-tooth voltage change we desired. The switch could also be replaced by a triode or pentode alternately biased to cut-off and then allowed to conduct.

Many other systems of obtaining linear sweeps have been devised for special circumstances.

CENTERING THE C.R.T. SPOT

Since we desire to control the position of the electron beam on the face of the tube, that is place it in any desired position, some form of adjustable deflection must be provided. This is most easily done by applying a D.C. voltage to the plates, but it can be done magnetically.

In applying an electrostatic means of centering we must do it in a push-pull manner or else the shape of the electron beam will be distorted. This means that if one plate is given a certain positive voltage the corresponding plate must be given an equal negative voltage.

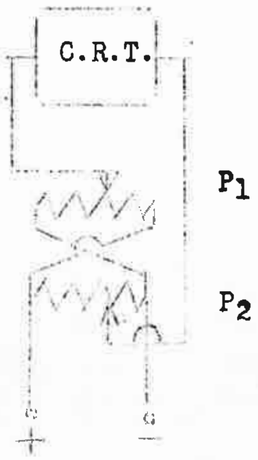


Fig. 19

In Figure 19 P_1 and P_2 are two identical potentiometers connected to the vertical plates as shown. Usually there are high resistances and by-pass condensers in the circuit between the potentiometers and the plates to isolate them. The shafts on the two potentiometers are fastened together so that if P_1 goes to the right, so does the slider on P_2. This arrangement ensures that the voltages will be applied to the plates in the proper manner. The magnitude of the deflection voltages depends on the deflection sensitivity of the C.R.T., and may be as little as 100 volts or as much as 600 volts, both positive and negative. A similar arrangement can be applied to the horizontal plates.

ANTENNAS

We have already seen that antennas can be designed to throw the radio waves in any desired direction, or to receive from any desired direction. If the conductor arrangement which goes to make up the antenna assumes some simple geometrical form such as a straight wire or possibly a circle both the radiating and directional properties can be calculated. However, in actual practice it is not always possible to use these simple forms, and much experimentation has been necessary to arrive at the best results.

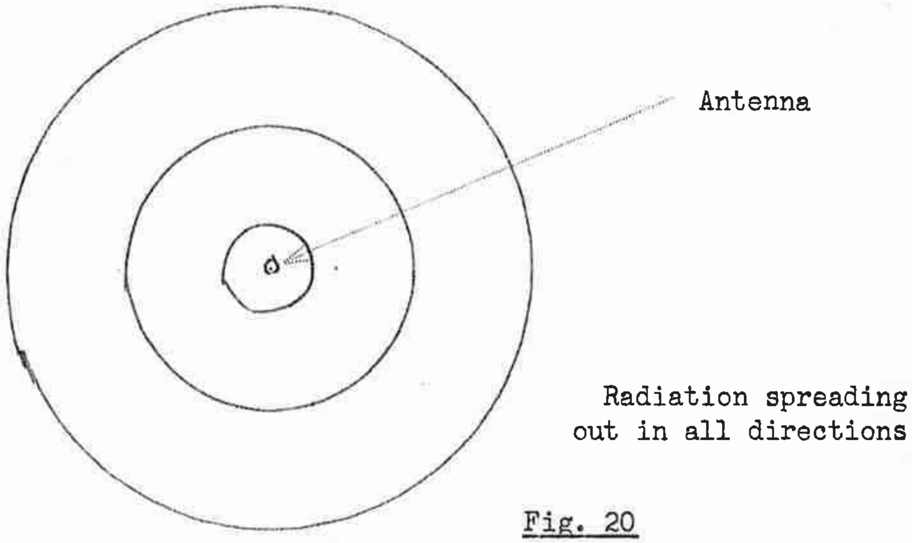


Fig. 20

Figure 20 shows the wave radiated from a single vertical aerial. If we look at this from the side the radiation pattern looks like Figure 21. By radiation pattern we mean that most of the radiation is confined to the area indicated.

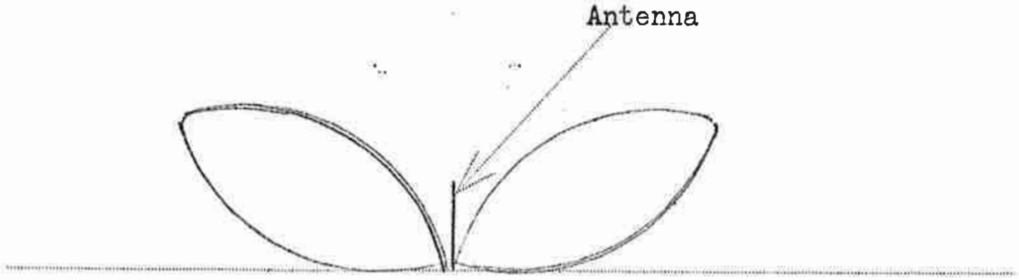


Fig. 21

We can imagine it as a doughnut surrounding the aerial. The patterns depend of course on the length of the vertical aerial compared with the wavelength radiated. Most systems of directive radiation depend on the waves from two or more radiating elements interfering with each other. These elements are usually half a wave length long but they might be grounded quarter wave antennas, flat top antennas, or even loops. An almost unlimited number of combinations is possible since their directive effects produced depend not only on the relative positions and spacing of the various antennas but on the amplitudes and phase of their currents as well, (by amplitude we mean height or size, and by phase we mean that any changes in voltage and current occur at the same time in each aerial if they are in phase and at different times if they are not in phase).

Perhaps the best known arrangement is that of a number of identical parallel antennas arrayed laterally along a straight line. Usually the antennas carry equal currents and oscillate in the same phase. This produces the strongest signal in a direction at right angles to the plane of the array and is known as a broad-side array. (See Figure 22.)

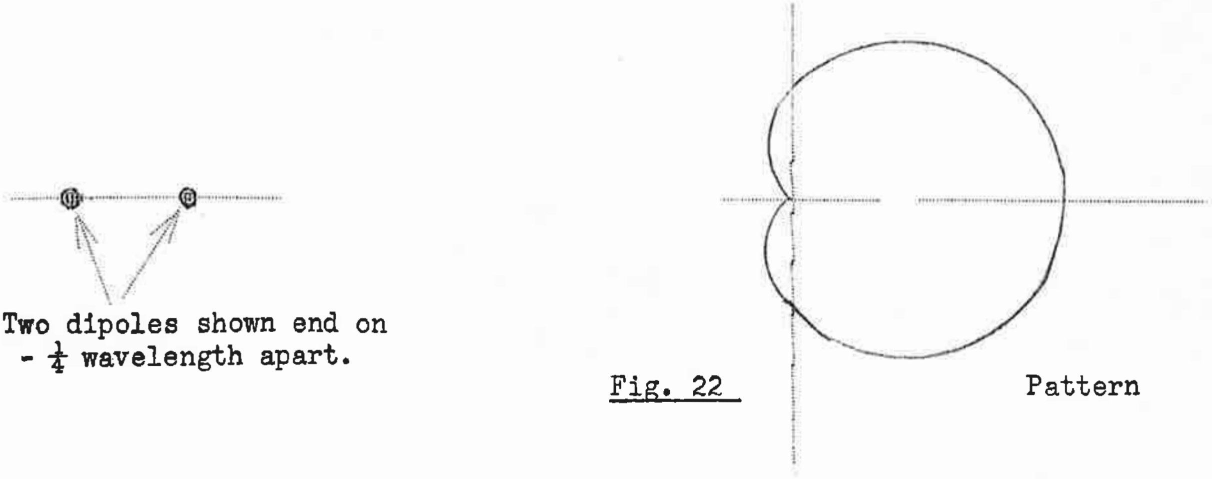
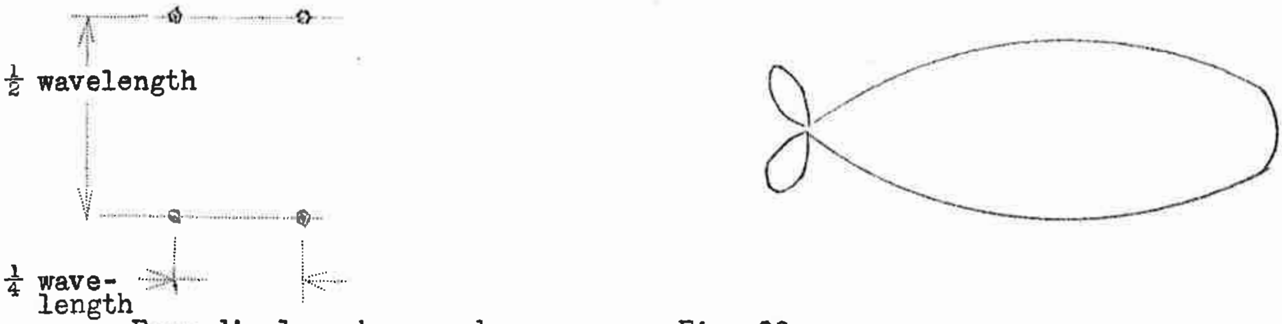


Fig. 22

If the directional arrangement contains two sets of identical antennas arranged as in Figure 23 the directional effect is much more marked.



Four dipoles shown end on.

Fig. 23

Sometimes as many as twenty-four antennas are arranged on the one structure particularly for shorter wave length work - this is usually called a billboard array.

Various combinations of aerials have come to be known by special names such as Yagi, Zepp, etc. A new form is a paraboloid with a dipole placed at its focus. In addition a parasitic dipole placed in front of the radiating dipole will help to concentrate the radiation into the paraboloid. The paraboloid pattern is shown in Figure 24 and is sausage shaped.

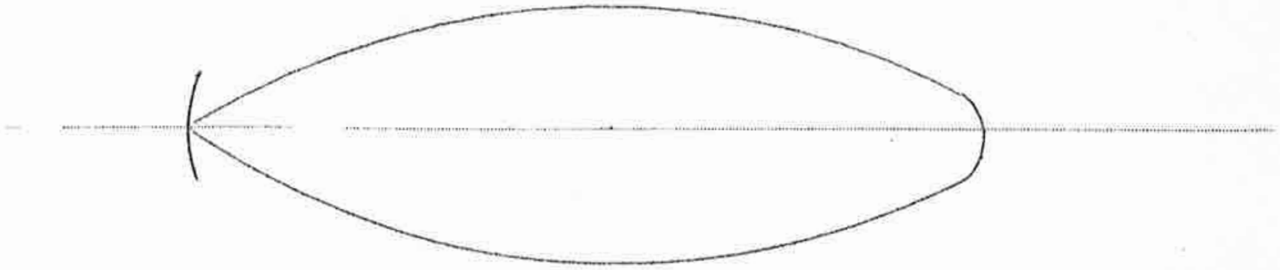


Fig. 24

USES OF R.D.F.

We have seen then that R.D.F. is a system of radio detection and position determination of objects based on the principle of reflected radio impulses using ultra-short wavelengths. The reflected echoes are registered on C.R.T.s and the distance, azimuth and elevation of the object is determined.

Since the functions of R.D.F. vary, so does the equipment ranging from large costly stations to relatively small inexpensive aircraft installations. There is no such thing as a universal set for all purposes and sets are in no way interchangeable.

The information obtained by R.D.F. is available immediately definitely and accurately so long as the equipment is functioning.

R.D.F. represents such an advance in the science of war that it is difficult to determine its strategical and tactical effects in the future. Large numbers of specially trained operators and technical men are needed.

Since R.D.F. is independent of weather, fog, clouds or mist which often reduces visibility to the vanishing point, it provides additional eyes when they are most needed.

This article has been an attempt to present in a simple form the highlights of R.D.F., its meaning and a few of its applications in a general way.

June 1941 R.G. Campbell