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Colin Hinson
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AIR PUBLICATION 2514
Volume I

R. A. F.
SHORTWAVE COMMUNICATION HANDBOOK

PREPARED BY DIRECTION OF THE MINISTER OF AIRCRAFT PRODUCTION

A. Rowlands

PROMULGATED BY ORDER OF THE AIR COUNCIL

A. W. Street

AIR MINISTRY
JANUARY 1943

R.A.F. SHORTWAVE COMMUNICATION HANDBOOK.

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Chapter 3.

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CHAPTER 1.

Radio Waves.

1. (i) Radio waves are electromagnetic waves identical, except for wavelength or frequency, with heat and light waves. They travel in space with the same average speed of 300,000,000 metres per second and this figure gives the relationship between frequency and wavelength, i.e. frequency multiplied by wavelength equals velocity. Thus, a wave 300 metres long has a frequency of 1 megacycle per second.

(ii) As with light, radio waves can be reflected, refracted and diffracted. Reflection will take place whenever they meet a sudden change in medium, provided the area of the change in medium is about a wavelength square. Thus, short waves may be reflected by a mountain but long waves will bend over it. This bending round obstructions is called diffraction. Refraction occurs whenever waves obliquely enter a medium differing in refractive index. This is caused by that part of the wave first entering the new medium travelling faster or slower than that part still outside, thus changing the direction of the wave front. The actual composition of the medium in which electromagnetic waves travel is not known, but is referred to as the ether and is assumed to fill all space.

(iii) Electromagnetic waves are normally polarised, and the plane of polarisation is given by the plane of the electrostatic field. This field corresponds to the voltage of the wave; thus waves radiated from a vertical aerial have their electrostatic field in a vertical plane and are said to be vertically polarised. The electromagnetic field of which the wave is also composed is at right angles to the electrostatic field and corresponds to the current of the wave. The field strength of a wave is the measure of its intensity, expressed usually as microvolts per metre, and is the voltage developed between the ends of a piece of wire one metre long, placed with its axis parallel to the direction of polarisation. This voltage is produced partly by the electrostatic field, and partly by the electromagnetic field which, in cutting the wire at right angles, induces a voltage in it. As both fields are in phase, i.e. both the positive electrostatic and the positive electromagnetic fields arrive at the same instant, the voltages induced will add.

(iv) Waves are divided into the following groups:-

1.	Very low frequencies (very long waves)	10 - 30 k.c/s	(30,000 - 10,000 m.)
2.	Low frequencies (long waves)	30 - 300 "	(10,000 - 1,000 m.)
3.	Medium frequencies (medium waves)	300 - 3000 "	(1,000 - 100 m.)
4.	High frequencies (short waves)	3 - 30 m.c/s	(100 - 10 m.)
5.	Very high frequencies (very short waves)	30 - 300 "	(10 - 1 m.)

Propagation.

2. (i) Fig. 1 shows a general picture of waves of various frequencies leaving an aerial and the various paths over which they travel. It will be seen that the highest point reached by the waves is either the "E" or "F" layer. These layers are bands in the rarefied air above the earth, ionized and thus made partially conductive by ultra violet radiation from the sun. The highest frequency which a layer can reflect depends directly upon the density of ionization, and relative values for "E" and "F" layers are shown plotted against height above earth in Fig. 2. The "F" layer splits during the day time into two parts F_1 and F_2 which recombine slowly in the evening. As the layer ionization density depends upon radiation from the sun, it naturally falls during the night and is lowest shortly before sunrise; this means that the highest usable frequency varies with the time of day and this variation is discussed more fully

in paragraph 18.

(ii) Very long and long waves are vertically polarised, and being unable to penetrate the "E" layer, travel bounded by the "E" layer and earth as in a transmission line, the attenuation of which is low and inversly proportional to the square root of the wavelength.

(iii) Medium waves are usually vertically polarised, and have only a limited range, as they are rapidly attenuated by earth losses and are reflected but poorly from the "E" layer.

(iv) Short waves are vertically or horizontally polarised and have world wide range. The ground wave is rapidly lost but communication is maintained by a series of hops between the "E" or "F" layer and the earth. As long distance point to point communications are now carried out mainly by short waves, their behaviour and propagation will be discussed more fully in succeeding chapters.

(v) Very short waves are in general of use only over optical or slightly greater ranges, as their attenuation along the ground is rapid and the frequency is so high that they are only occasionally reflected by the "F" layer.

(vi) Fig. 3 shows the effective communication range of various wavelengths.

Short Wave or H.F. communication.

3. (i) As the wavelength is now small, it is possible to design aerials to form rays or beams of energy. These may travel direct from transmitter to receiver, if the distance is short, or may be reflected back and forth between "E" or "F" layer and earth several times, if the distance is very great. The attenuation of the ground wave is rapid, so that it can only be used up to a hundred miles or so for frequencies of three m.c/s (100 metres); and may only be of use up to 40 or 50 miles at 20 m.c/s (15 metres).

(ii) Rays leaving the aerial above about five degrees to the horizontal, travel straight until they reach the "E" layer where they are doubly refracted, and at the same time somewhat attenuated before passing on to the "F" layer, where the ionic density is great enough to bend them back towards the earth. This bending back which in effect is reflection is actually a continuous refraction, i.e. the gradual instead of sudden change in the refractive index of the layer causes the wave to follow a curved path. (For full details see A.P. 1093 chapter xiv, para. 27) If the frequency of a wave is above a certain critical value depending on the layer density, then the wave will penetrate the layer and emerge travelling in the same direction, but displaced sideways as shown in Fig. 1(c). Attenuation occurs during this bending and further refraction and attenuation occur at the "E" layer before the earth is reached. During this process irregular variations in layer density may change the wave direction in a random way, so that a ray does not necessarily return at the same angle as it left, although it will usually do so.

(iii) Unlike Long waves the attenuation of the H.F. sky wave is approximately proportional to the square of the wave length, thus the shorter the better. There is a limit to this however, for above 30 m.c/s (10 metres) the "F" layer density is seldom sufficient to bend the waves back to earth. Also, as the layer density varies with the time of day the highest usable frequency varies with it, as is indicated by the curves in Fig. 12 which gives the highest usable frequencies for ranges up to 1,200 miles for various places and times of day and year.

Changes in Polarisation

4. (i) The plane of polarisation of a wave is altered during refraction, so that a down-coming ray may be polarised in any direction, and the plane of polarisation may rotate. In which case the wave is said to be circularly

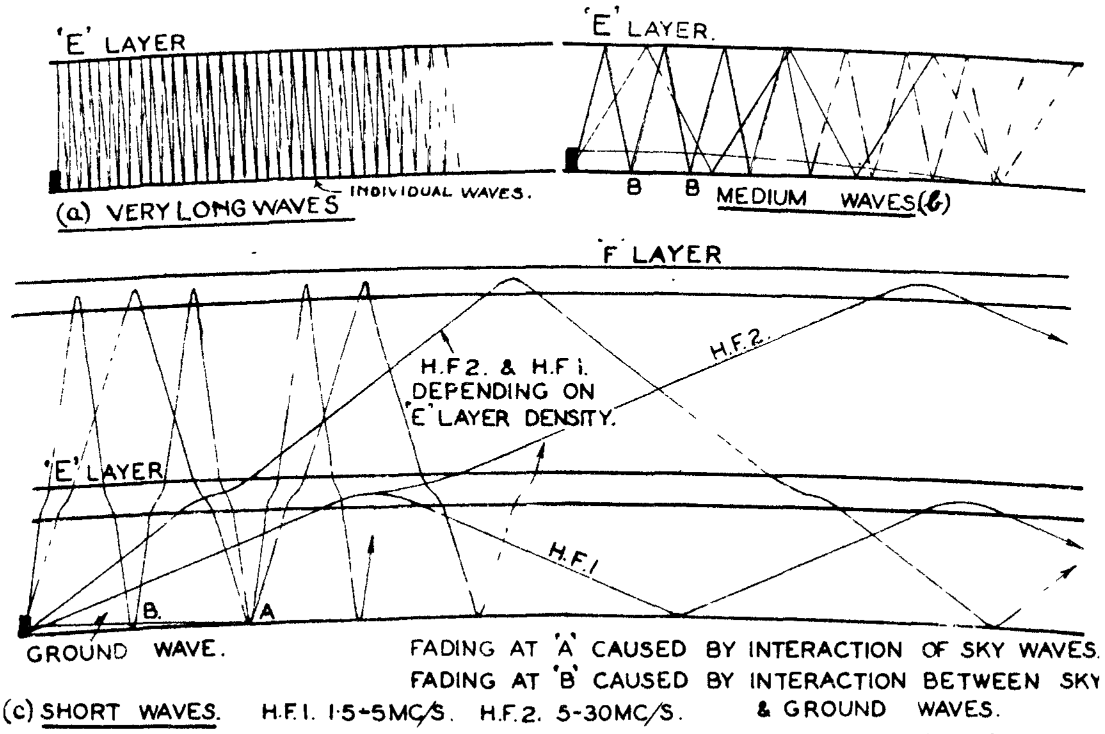


FIG. NO. 1.

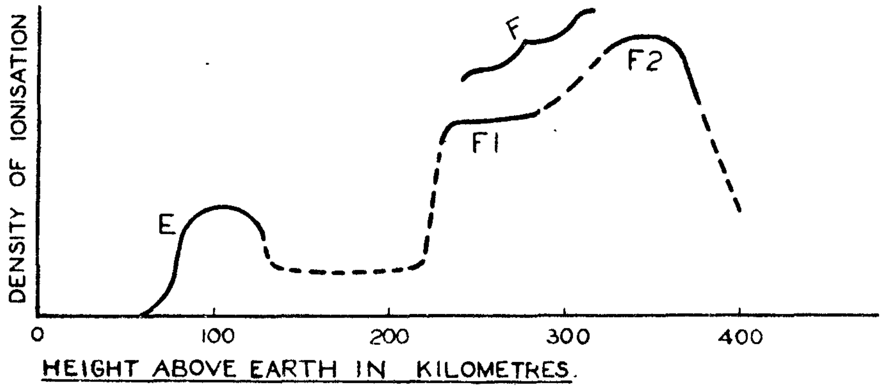


FIG. NO. 2.

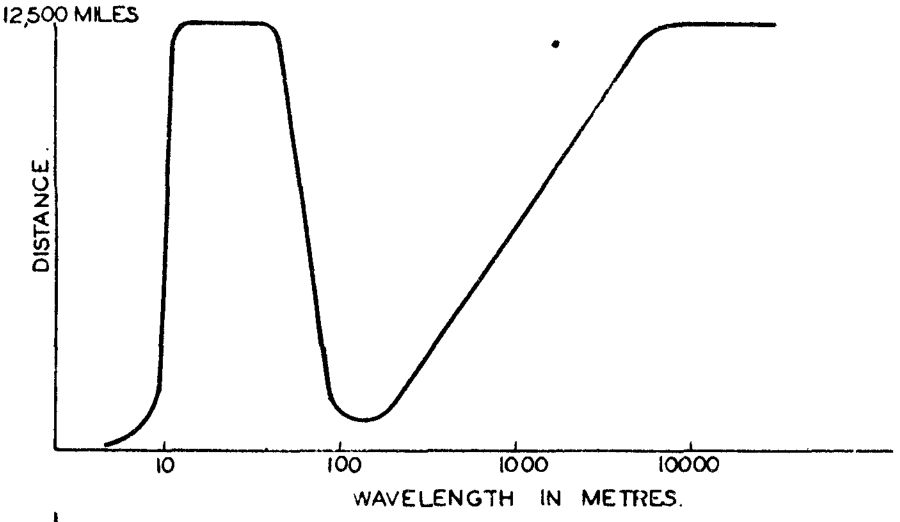


FIG. NO. 3.

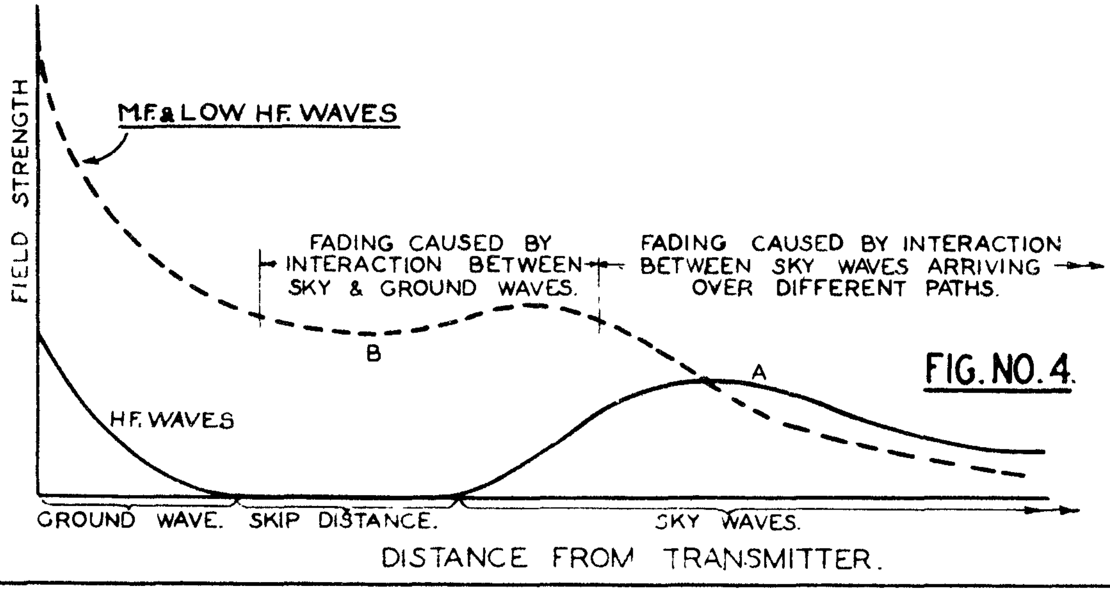


FIG. NO. 4.

polarised. If the field is stronger in one plane than another while rotating, the wave is said to be elliptically polarised. This means that an aerial responsive mainly in one plane; e.g. a horizontal dipole; receiving such waves would experience severe fading. A change of polarisation and simultaneous attenuation also occurs during reflection from the earth, and, as might be expected, the actual values depend on the angle of incidence, the polarisation of the arriving wave, and the ground conductivity and permitivity.

(ii) The curves of Figs. 5, 6, & 7 show that horizontally polarised waves suffer the least attenuation and phase change on reflection; and indicate the big difference between reflection losses from sea or hard ground. This shows clearly the importance of choosing a transmitting or receiving site where the ground is moist, and of high conductivity. For an M.F. or H.F. D.F. site this consideration is of vital importance, as D.F. aerials rely solely on the vertical component of the wave for operation.

Fading.

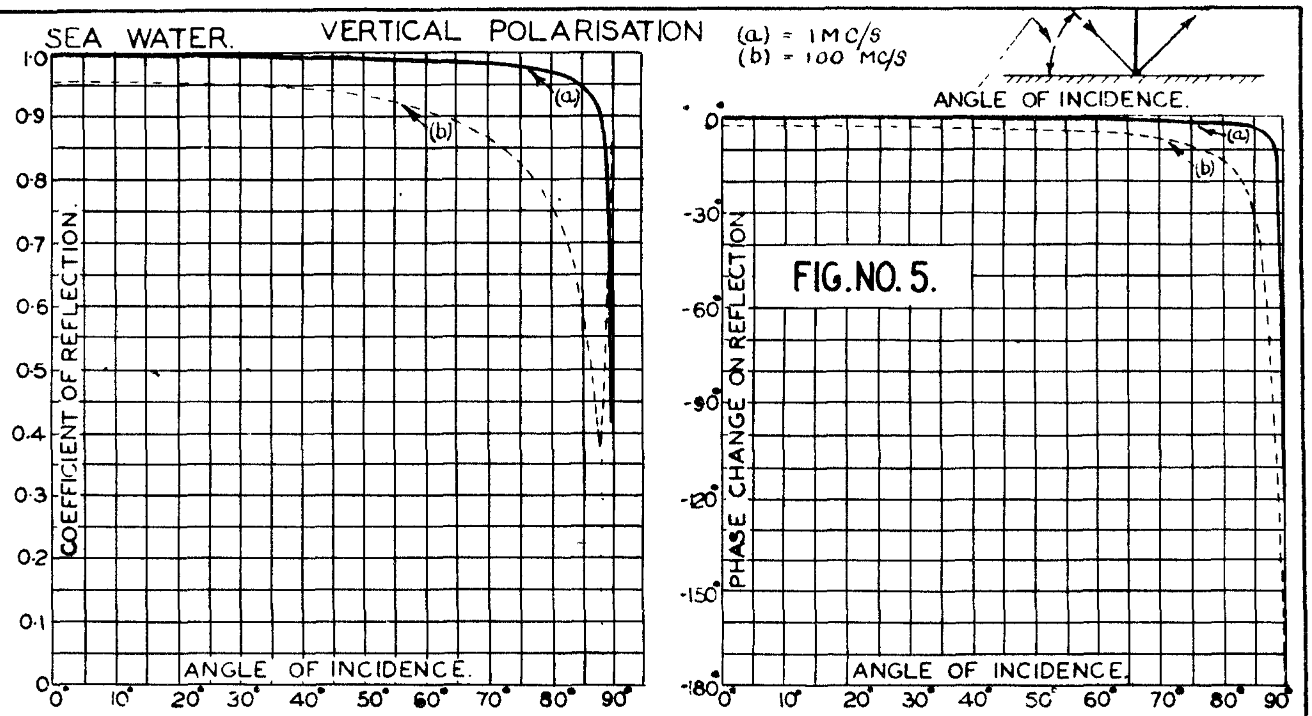
5. (i) Fading is most commonly caused by the interaction between waves arriving by different routes which alter slowly in length, thus changing the relative phase of the waves at the receiving aerial. Interaction between ground and sky waves, if the receiver is close enough to the transmitter for the ground wave to be present, and provided the frequency is low enough for the sky wave to be returned, will cause fading; as the path length and thus the relative phase of the reflected ray will change with varying layer height. Where the frequency is higher this high angle radiation will not be returned, and a gap, in which no signal is heard, will exist between the end of the ground wave and the sharpest down-coming wave. This gap is called the skip distance. The solid line of Fig. 4 shows this condition, while the dotted curve shows the effect for a lower frequency. In the part of the solid line marked "A", fading may be experienced, if signals are being received by two or more routes, as shown in Fig. 1.

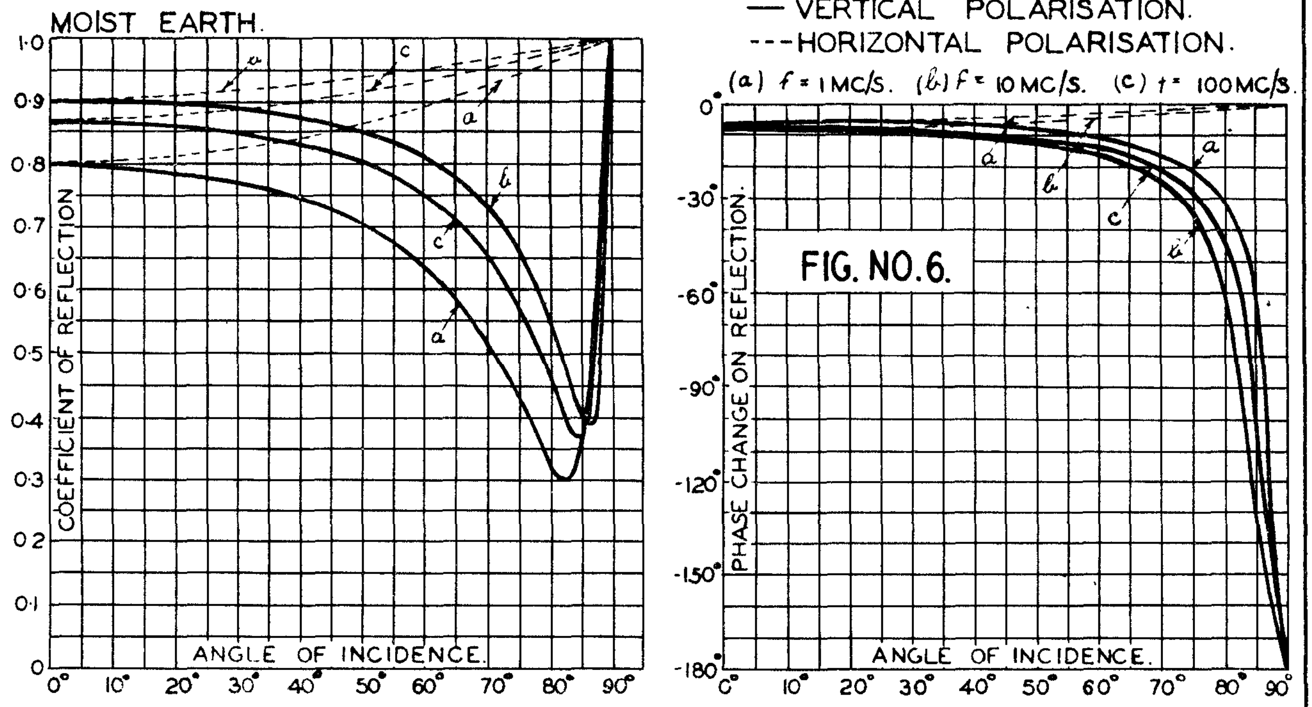
(ii) As the amount of bending of a ray depends on its frequency, it is evident that a modulated signal, which consists of a group of frequencies, may suffer more bending of the lower frequencies. Thus the relative amplitudes at the receiver will be altered and the result appear as audio frequency distortion; this is known as selective fading. For the same reason there is less chance of receiving a single frequency continuously than some of a modulated signal. In some continuous wave transmitters designed to make use of this effect, the frequency is varied a few hundred cycles per second by the same amount, thus transmitting a small group of frequencies and overcoming the effects of fading.

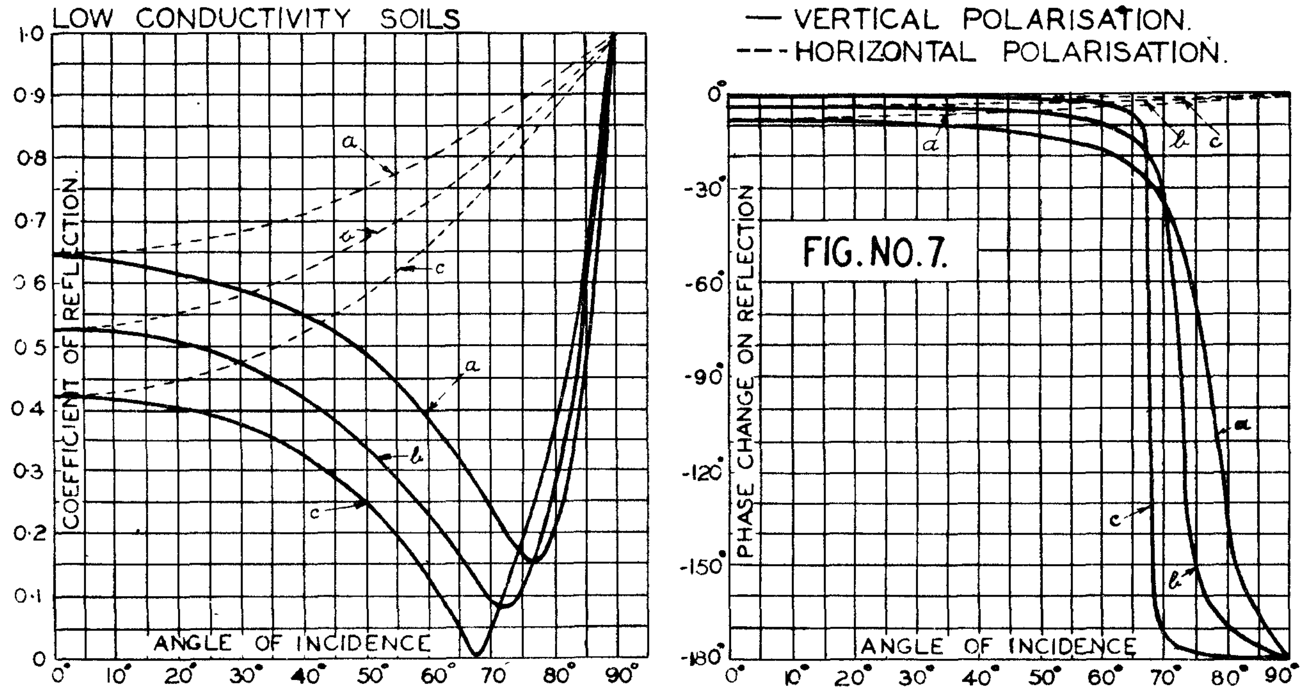
Great Circle Bearings.

6. (i) It has been seen that communication is carried on by means of rays, consequently it is necessary for best results to direct these in both vertical and horizontal planes. The means to this end lie in the aerial and its orientation.

(ii) Waves normally travel along great circle routes, that is, they travel between two places along the circumference of a circle, which passes through the places, and has its centre at the centre of the earth. All lines of longitude are great circles, but of latitudes the Equator is the only great circle. Since a great circle passes all round the world there are two routes by which waves can reach a given station, and except in the one case, where the distant station is diametrically opposite, and there are an infinite number of paths, one route will be shorter than the other. It is over this shorter route that radio waves are normally sent or received. The exact calculation of distances and bearings is a matter of considerable difficulty, as the earth is not a perfect sphere, but for radio and D/F purposes it may be assumed to be spherical, and this makes the problem much simpler.







(a) FINE SANDS AND GRAVELS.
(b) SHINGLES AND GRITS.
(c) HARD ROCKS.
} f = 10 MC/S

REFLECTION COEFFICIENTS.

Suitable Map Projections for Direct Measurement.

7. (i) For all normal work, when the higher degree of accuracy afforded by calculation is not essential, great circle bearings and distances are usually measured direct on a suitable map. Since a map projection is a mathematical representation of the surface of a sphere, and since it is impossible accurately to represent the surface of a sphere as a plane surface, no map projection is accurate in all respects. The four factors which are involved are:-

(a) Shape
(b) Area
(c) Scale of distance
(d) Direction (bearings)

Maps can be designed to be perfectly accurate in one or other of these four factors, but never simultaneously in all four. Thus, for the measurement of great circle bearings a map projection which gives great circle bearings correctly, irrespective of its inaccuracy in the other factors, will be required. For D/F purposes, the normal projection used is the "Gnomonic"; on which any straight line is a great circle whose true bearing can be measured directly from the meridian passing through the station where the bearing is required. If distances are required as well, a Gnomonic projection is not suitable, since its scale is not constant and varies all over the sheet. It is usual, for all normal purposes, to use one of the various projections which have been designed to give the best average results in respect of all four factors, but which are not absolutely accurate in any of them. The most common of these is the International Polyconic, which now covers most of the world. This projection has an almost constant scale, and thus distances can be measured fairly accurately, and straight lines depart from great circles by less than 1° in 1,000 miles or so. For shorter distances, the great circle bearings and distances measured on this type of projection, can be considered well within the accuracy obtainable by the radio apparatus itself, and is thus recommended for use when direct measurement is resorted to as opposed to calculation. Calculation is usually desirable for distances greater than 1,000 miles.

(ii) Another type of projection which is commonly used, especially by navigators and almost universally by the Navy, is Mercator's. Its chief feature, and the reason for its widespread application to navigation, is that a straight line drawn on Mercator's projection is a "rhumb line"; that is, a line which cuts all meridians at the same angle, as opposed to a great circle whose angle of intersection with successive meridians, with the exception of the Equator, increases or decreases depending upon its direction. To achieve this property, the projection will require an arrangement of meridians which are parallel straight lines and thus do not converge towards the poles as in the case of other projections. The parallels of latitude on Mercator's projection are also parallel straight lines at right angles to the meridians but not equally spaced as are the meridians. The distance between each parallel of, say, 10° intervals increases towards either pole. Thus, Mercator's projection is an easy one to recognise by a glance at its graticule (lines of latitude and longitude) and Figure 8 is a diagram of the world on Mercator's graticule.

(iii) In Figure 8 the straight line A - B is a rhumb line between the points A and B, and the curved line, which is convex towards the nearest pole, is the corresponding great circle. If the angle between the straight rhumb line and the great circle can be calculated, then use can be made of this projection for measuring great circle bearings. Fortunately, this is a simple matter since this angle, which is known as the "conversion angle" is given by the following formula:-

$$\text{Conversion Angle (C.A.)} = \tfrac{1}{2}\ \text{d long X sine mid lat.}$$

where "d long" is the difference in longitude between A and B, and, "mid lat." is the latitude of a point midway between A and B.

Thus, the procedure for obtaining a great circle bearing from Mercator's projection is as follows:-

(1) Join the two places with a straight line, and with a protractor measure its bearing from North at the home station, i.e. in Fig. 8 bearing at B is 256° and at A 76°

(2) Note the longitude of each place and thus compute the difference in longitude (d long)

(3) Note the latitude of the mid-point (mid.lat.)

(4) Using the formular above calculate the conversion angle (C.A.)

(5) Remembering that the great circle is always convex towards the nearer pole, add or subtract the conversion angle from the measured bearing. This gives the great circle bearing required.

(iv) The measurement of distance on Mercator's chart is achieved by using the scale of latitude down the Eastern or Western edge of the sheet. It is essential that the portion of scale in the same latitude region as the line in question be used, since it will be noticed that the latitude scale is not a constant one but increases towards the poles. 1° of latitude represents 69.07 statute miles or 60 nautical miles. The scale of longitude must never be used for measuring distance as this does not represent miles.

(v) Details of maps suitable for radio purposes, such as the foregoing, can be obtained from A.D.Maps, Air Ministry, who is the authority for the provision of all maps in the Royal Air Force.

Calculation of Great Circle Bearings.

8. (i) To calculate great circle bearings it is necessary to use formulae based on spherical trigonometry. The simplest of these giving the bearing only and known as the Four Parts formula is:-

$$\text{Cot. } A = \frac{\text{Sin } b \cot a}{\text{Sin } N} - \cot N \cos b$$

where, as illustrated in Fig. 9 angle A is the great circle bearing of B from A, i.e. the required angle; a is the angular distance of station B from the North Pole; b is the angular distance of Station A from the North Pole, and N the polar angle, is the difference in longitude between A and B.

(ii) Note on a and b. Since a or b is the angular distance of stations B or A respectively from the North Pole the rule is:-

If B or A is in the Northern Hemisphere, then
a or b = 90° - Lat. B or A.

But if in the Southern Hemisphere, then
a or b = 90° + Lat. B or A.

(iii) Note on the Polar Angle N. As this angle is the difference in longitude (d long) between A and B, it follows that if the two longitudes are in the same hemisphere it is necessary to subtract one from the other, but if in opposite hemispheres to add them together. Since there are two routes the result of this addition may be greater than 180°, i.e. the route is longer than half way round the world, and if so the sum of the longitudes must be subtracted from 360° to give the angle for the shorter route.

Example.

9. (i) Suppose the great circle bearing is required of Melbourne(B) from Aden (A)

Map Of The World On Mercator's Graticule.

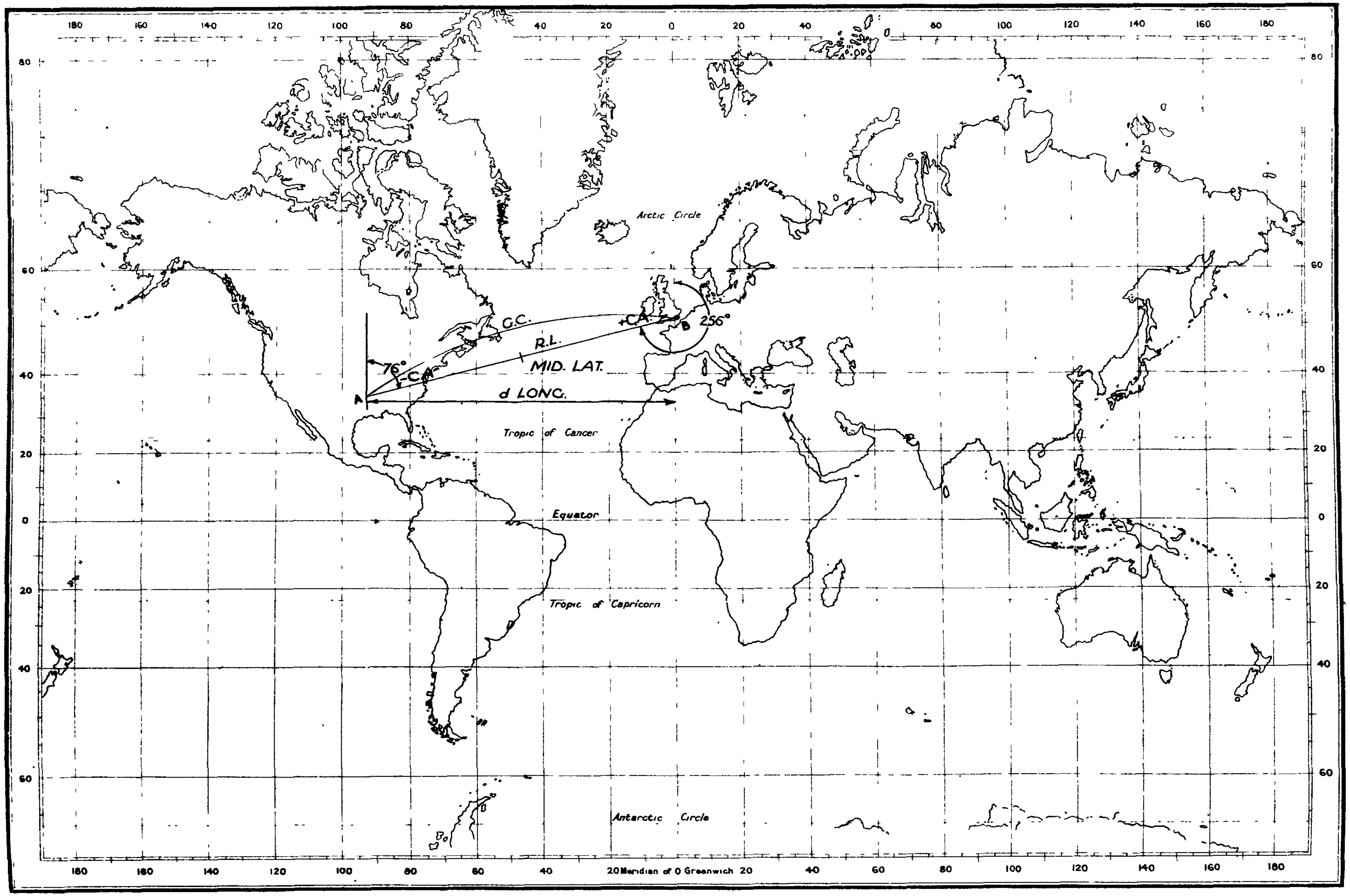


Fig. No. 8

(A) Aden Lat. 12° 46' N. Long. 45° 2' E.
(B) Melbourne Lat. 37° 50' S. Long. 145° E.

Then the Polar Angle N (d long) = 145° - 45° 2' = 99° 58'

$$\begin{array}{lllll} a & = & 90^\circ + 37^\circ\,50' & = & 127^\circ\,50' \\ b & = & 90^\circ - 12^\circ\,46' & = & 77^\circ\,14' \end{array}$$

But if an angle "X" is greater than 90° but less than 180°

then

$$\begin{array}{lll} \text{Sin } X & = & + \text{Sin } (180 - X)^\circ \\ \text{Cos } X & = & - \text{Cos } (180 - X)^\circ \\ \text{Tan } X & = & - \text{Tan } (180 - X)^\circ \\ \text{Cot } X & = & - \text{Cot } (180 - X)^\circ \end{array}$$

and from the formula,

$$\text{Cot } A = \frac{\text{Sin } 77^\circ\,14' \text{ cot } (180^\circ - 127^\circ\,50')}{\text{Sin } (180^\circ - 99^\circ\,58')} - \text{Cot } (180^\circ - 99^\circ\,58') \text{ cos } 77^\circ\,14'$$

$$= \frac{\text{Sin } 77^\circ\,14' \text{ X } - \text{Cot } 52^\circ\,10'}{\text{Sin } 80^\circ\,2'} - (-\text{Cot } 80^\circ\,2' \text{ X Cos } 77^\circ\,14')$$

$$= - 0.7303.$$

Angle A = 53° 51' from tables, but the minus sign indicates that the actual angle, and therefore the great circle bearing required, is:-

$$180^\circ - 53^\circ\,51' = \underline{126^\circ\,09'}$$

(ii) If the bearing of A from B is required then the triangle NAB may be relettered to suit, i.e. replacing A by B etc., or alternatively the formula can be altered:-

$$\text{Cot } B = \frac{\text{Sin } a \text{ Cot } b}{\text{Sin } N} - \text{Cot } N \text{ Cos } a$$

This will give angle B, but since bearings are measured from North the actual bearing will be 360° - angle B.

Calculation of Distance.

10. (i) In order to find the distance between A and B it is necessary to evaluate angle n, and this is given by the following formula:-

$$\text{Cot } n = \frac{\text{Sin } A \text{ Cot } N}{\text{Sin } b} + \text{Cos } A \text{ Cot } b$$

Having obtained this angle it is converted into statute miles by multiplying by 69.07, or by 60 to give nautical miles, i.e.:-

1° = 69.07 statute miles or 60 nautical miles.
1' = 1.151 statute miles or 1 nautical mile.

(ii) Example. To find the distance between Aden and Melbourne from the above formula.

$$\text{Cot } n = \frac{\text{Sin } 126^\circ\,09' \text{ Cot } 99^\circ\,58'}{\text{Sin } 77^\circ\,14'} + \text{Cos } 126^\circ\,09' \text{ Cot } 77^\circ\,14'$$

$$= - 0.2792$$

$$n = 180^\circ - 74^\circ\,24' = 105^\circ\,36'$$

Therefore distance = 105° 36' X 69.07 = 7293 miles.

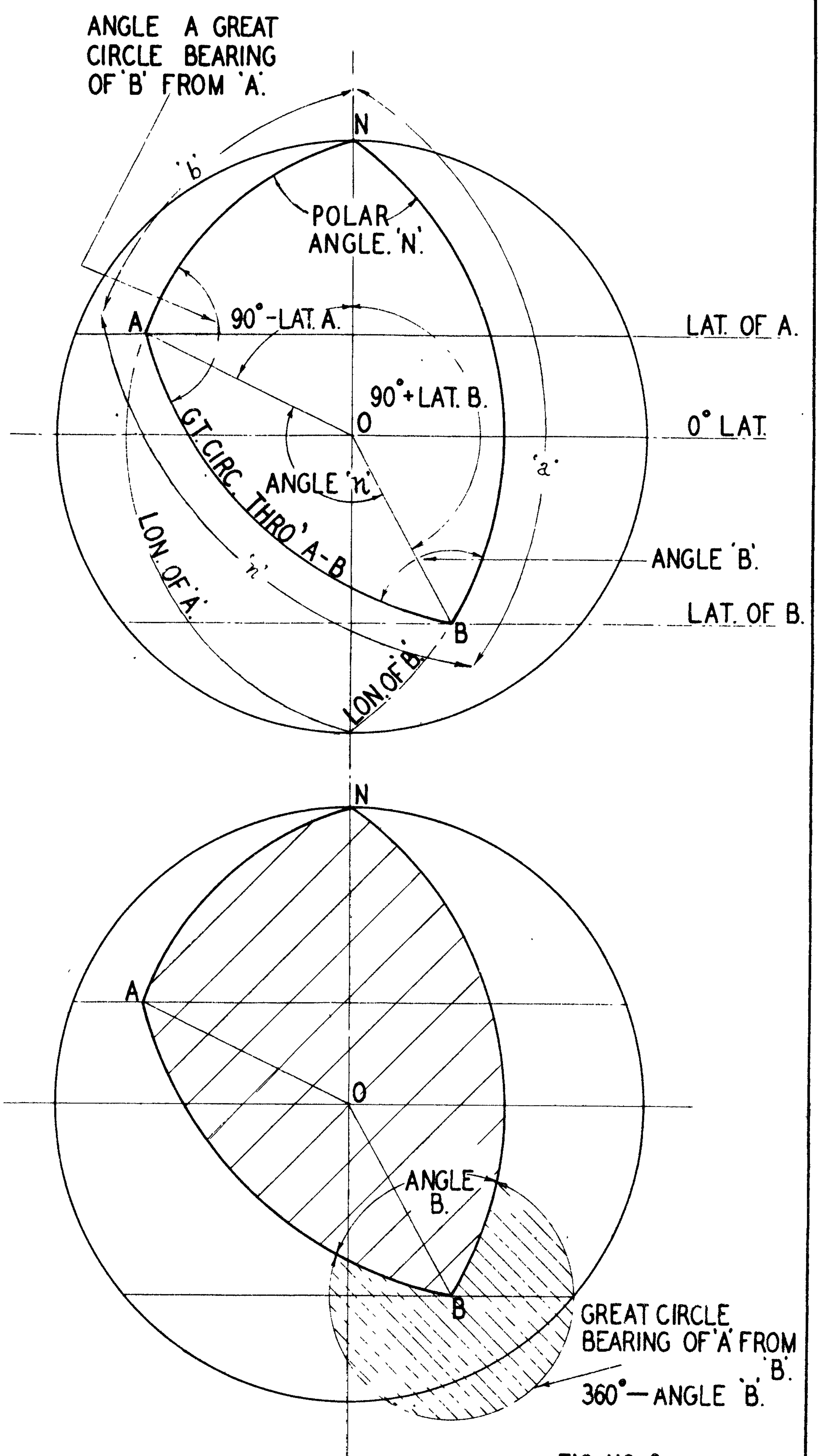

ANGLE A GREAT CIRCLE BEARING OF 'B' FROM 'A'.
N
'b'
POLAR ANGLE. 'N'.
A
90° - LAT. A.
LAT. OF A.
90° + LAT. B.
O
0° LAT.
GT. CIRC. THRO' A-B
ANGLE 'n'
'a'
LON. OF 'A'.
'n'
ANGLE 'B'.
LAT. OF B.
B
LON. OF 'B'.
N
A
O
ANGLE B.
B
GREAT CIRCLE BEARING OF 'A' FROM 'B'.
360° — ANGLE 'B'.

FIG. NO. 9.

Determination of Great Circle Distance using Haversines.

11. (i) In the formula used above for finding the distance, it is necessary to know the great circle bearing and use this to obtain the distance. Where the bearing is not required, the working can be simplified by employing a formula based upon the use of an arbitrary ratio known as a "Haversine", which is $\frac{1 - \text{Cosine}}{2}$. The values of this ratio are given in all nautical tables as well as those of sine, cosine, and tangent.

(ii) The Natural Haversine formula is the name given to the expression for distance which is:-

Haversine n = Sin a Sin b Hav N + Hav d lat

where a, b, n, and N have the same significance as before, and d lat is the angular difference in latitude between A and B. For greater convenience of operation this formula may be re-written:-,

Haversine (G.C.D.) n = Cos lat A Cos lat B Hav d long (N)
+ Hav d lat.

(iii) Example. To find the great circle distance between Portsmouth and Buenos Aires.

Portsmouth	Lat. 50° 48' N.	Long. 01° 06' W.	(A)
Buenos Aires	Lat. 34° 37' S.	Long. 58° 48' W.	(B)

Then from the above formula -

Hav n = Cos 50° 48' Cos 34° 37' Hav 57° 42' + Hav 85° 25'

Using Log Functions,

Log Cos 50° 48' = $\bar{1}$. 80074
Log Cos 34° 37' = $\bar{1}$. 91538
Log Hav 57° 42' = $\bar{1}$. 36703

Log function ø = 1 . 08315

Anti Log function ø = 0 . 12110
Natural Hav 85° 25' = 0 . 46005

∴ Natural Hav (G.C.D.) n = 0 . 58115

and from tables n = 99° 20.5'

Thus the great circle distance is

99° 20.5' x 69.07 = 6861 statute miles.

(iv) Great circle bearings can also be obtained by using Haversine formulae, but with these formulae it is first necessary to find the angular value of n the distance between the stations, so that they have no advantage over the Four Parts Formula in Para. 8 (i)

(v) For the solution of these problems any good book of five or six figure nautical tables which contains the necessary trigonometrical ratios may be used. Norie's or Inman's are recommended.

Graphical Solution of Great Circle Bearings.

12. (i) Where trigonometrical tables are not available for obtaining a calculated solution the following graphical method will give the bearing required. This method is based upon the ordinary rules of geometrical projection and the previous notation is used, i.e.

A is the location of the station requiring the bearing

B is the location of the distant station.

N is the North Pole.

(ii) The object is to obtain a projection which will show the true angle between a great circle passing through A and N and a great circle passing through A and B. This condition is met when A is brought to the centre of a circle with B and N in their correct relative positions. In this projection - see Fig. 10A - the two great circles appear as diameters and the great circle bearing of B from A is the angle between them.

Polar Angle.

13. (i) It is first necessary to find the polar angle N (d long) between A and B, as detailed in para. 8 (iii), i.e.:-

(1) When A and B are both East or West longitudes the polar angle is the difference in their longitudes.

(2) When either A or B is an East longitude and the other a West longitude then:-

(a) The polar angle is the sum of the longitudes if it is less than 180°

or (b) 360° minus the sum of the longitudes if greater than 180°

Procedure and Location of Fixed Points.

14. (i) When constructing the diagrams and locating fixed points the notes and procedure given below must be closely followed, and should be read through in conjunction with Fig. 10 (b-d) before starting to draw. Each step must be completely understood before proceeding to the next, and the larger the diagrams are drawn the greater will be the degree of accuracy obtainable. In all projections take care to maintain A, B and N in their correct relative positions.

(1) Draw a plan circle with an Elevation circle immediately below it and locate A and B in plan and elevation as in the appropriate figure.

(2) A is on the horizontal centre line of the plan circle either to the right or left of N and is:-

(a) to the right of N when	) Longitude of A is East of the longitude of B (13(1))) A is on an East Longitude (13 (2a))) A is on a West Longitude (13 (2b))
(b) to the left of N when	) Longitude of A is West of the Longitude B (13 (1))) A is on a West Longitude (13 (2a))) A is on an East Longitude (13 (2b))

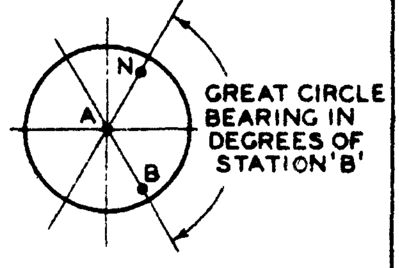


FIG. 10A.

EXAMPLE.1. IT IS REQUIRED TO DETERMINE THE GREAT CIRCLE BEARING OF BERMUDA (B) FROM WELLINGTON (A)

A – LAT. 41° 65' S
LONG. 174° 48' E

B – LAT. 32° 19' N
LONG. 64° 51' W

N = NORTH POLE

I OBTAIN POSN.'A' IN PLAN FROM DIM. W IN ELEVATION = LENGTH N.A

II OBTAIN POSN.'B' IN PLAN FROM DIM. X IN ELEVATION = LENGTH N.B

III OBTAIN POSN.'B' IN ELEVATION BY PROJECTING DOWNWARDS FROM 'B' IN PLAN

IV USE LENGTH 'Y' IN PLAN TO OBTAIN POSN.'B' IN PROJECTION CIRCLE.

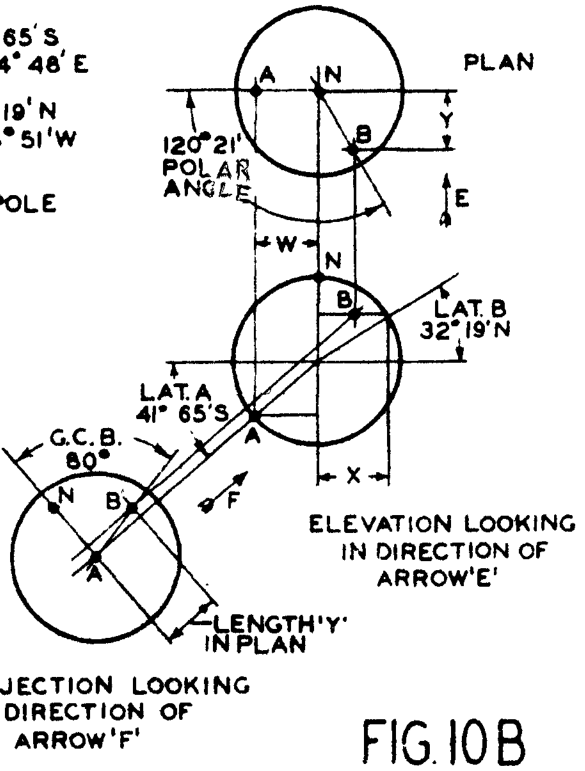
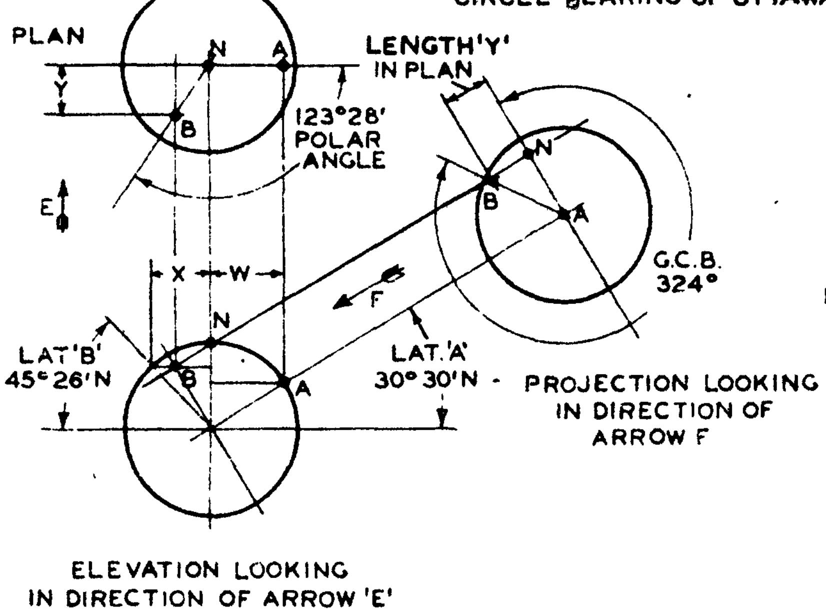


FIG. 10 B

EXAMPLE. 2. IT IS REQUIRED TO DETERMINE THE GREAT CIRCLE BEARING OF OTTAWA (B) FROM SHAIBAH (A)



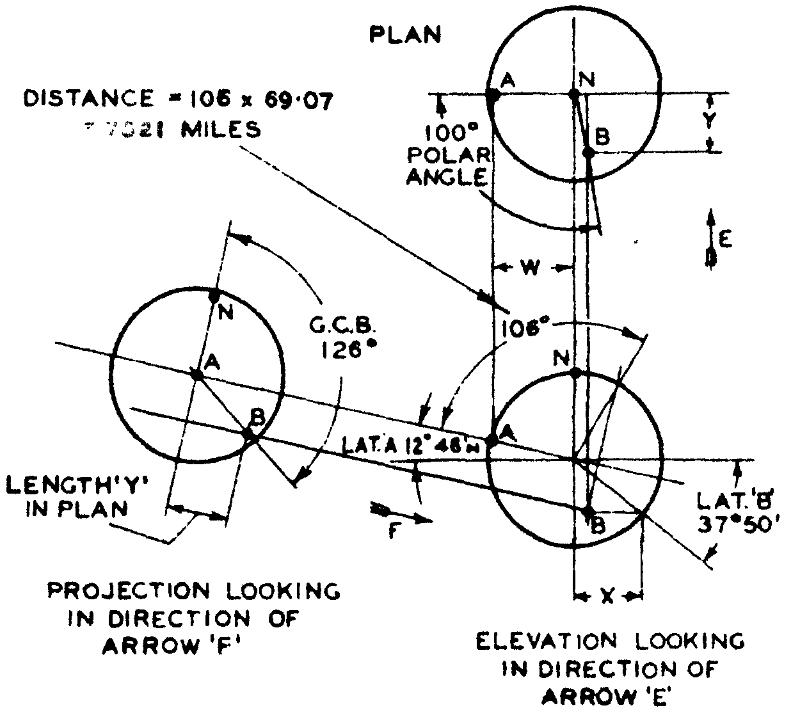
A – LAT. 30° 30' N
LONG. 47° 48' E

B – LAT. 45° 26' N
LONG. 75° 40' W

N – NORTH POLE

FIG. 10 C

EXAMPLE 3. IT IS REQUIRED TO DETERMINE THE GREAT CIRCLE BEARING OF MELBOURNE (B) FROM ADEN (A)



A – LAT 12° 46' N
LONG. 45° 2' E

B – LAT. 37° 50' S
LONG 145° E

N – NORTH POLE

FIG. 10 D

(3) A is on the horizontal centre line to the right or left of N as above, and the length A - N = W is determined in (5) below.

(4) A in elevation is on the elevation circle at the angle of latitude (see figures)

(5) W = the length of the horizontal line from A in elevation to the vertical centre line.

(6) Draw the polar angle in plan so that B always comes in the lower semi-circle (see figures) and locate B on the line forming the polar angle. The length B - N = X (see 7 below)

(7) X = the length of the horizontal line from the point of intersection in elevation of the angle of latitude B on the circle, to the vertical centre line.

(8) B in elevation is along this horizontal line and is located by projecting downwards from B in plan.

Location of Fixed Points in Projection.

15. (i)
(1) A is any convenient point along the projection of the line forming the angle of Latitude A and the projection circle is drawn centred on A.

(2) N is on a line passing through A at right angles to the projection line above and is a great circle through A and N. It is not necessary to know the position of N on this line but it can be found by projection of N in elevation.

(3) To locate B project a line from B in elevation across the projection circle and the position of B on this line is determined by the length of Y in plan view (see figures)

(4) The length Y is the length of the vertical line from B to the horizontal centre line.

(5) Provided the system of projection as explained and illustrated is followed, B in projection will always be on the side of the projection circle nearer to the elevation circle, and the line through B from A will be a great circle. The angle between this line and the line through N from A is the great circle bearing required.

Distance Between A and B.

16. (i) The method for finding distance between A and B is illustrated in Figure 10d and the procedure is as follows:-

(1) In the elevation view draw a line through B at right angles to the line forming the angle of latitude A.

(2) From the centre of the elevation circle draw a line through one of the points of intersection on the circle, of the line drawn as in (1)

(3) Measure in degrees the angle formed by the line drawn in (2) and the line of the angle of latitude A.

(4) The distance in statute miles between A and B = the number of degrees measured in (3) multiplied by 69.07

Vertical Plane Propagation Angles

17. (i) In Para. 6 it was mentioned that for best results it is necessary to direct the radiation from aerials in both horizontal and vertical planes, and reference to Fig. 1(c) shows clearly the great changes in distance per hop and thus communication range with varying angles of propagation.

(ii) The actual distance per hop for a given angle, will depend on the virtual height of the reflecting layer, which in turn depends upon the time of day or night. Average values for day and night heights respectively are:-

E layer 90 and 100 Km.
F layer 250 and 350 Km.

From this data the curves of Fig. 11 are drawn, and from them the distance per hop for various propagation angles and layer heights can be determined, e.g. daylight communication over a distance of 3,000 miles with an aerial radiating at 10°- 12° would be carried out in three hops of 1,000 miles each, but at night with the same propagation angle two hops of 1,500 miles each would suffice. This is unlikely to be a practical case, however, for the ionization density of both E and F layers falls at night, with the result that a lower frequency must be used to maintain reflection from the layer, and consequently, communication. This fall in frequency causes the physical size of the aerial needed to radiate at low angles, to be very large and thus costly; a simpler aerial is therefore normally used and its propagation angle will probably be about twice the day angle. Thus, in the above example, communication at night would be by three hops of 1,000 miles each as in the day time.

Highest Usable Frequencies and Choice of Working Frequency.

18. (i) The variation of highest usable frequency for a given distance is directly dependent on the degree of ionization in the E and F layers. This ionization level is controlled almost entirely by the ultra-violet radiation from the sun, the strength of which depends on the following factors:-

(a) Time of Day
(b) Season of Year
(c) Location
(d) Sunspot activity.

(ii) The first three factors' effects are now faily well known, so that it is possible to draw the sets of curves of Fig. 12 (1 - 26) predicting the highest frequency usable for communication under many different circumstances. Too much reliance must not be placed on the curves, however, for as they are produced from average values, day to day variation of sunspot activity may render them slightly inaccurate. In general a frequency between 10 and 30% lower than that given by the curves will give the most satisfactory results, but the most suitable frequency can only be found by experiment over the circuit being worked.

Sunspot Activity.

19. (i) The fourth factor mentioned above varies in cycles of 27.3 days and 11 years; the first is the period of rotation of the sun, and variations caused by it are not usually very large and are normally neglected, the second is a general and fairly large cyclic change in radiation intensity. It is therefore necessary to apply the correction factors of Table I to compensate for this change. The numbers shown are percentage additions to the frequency indicated by Fig. 12.

LAYER HEIGHTS AND DISTANCE PER HOP FOR VARIOUS ANGLES OF PROPAGATION.

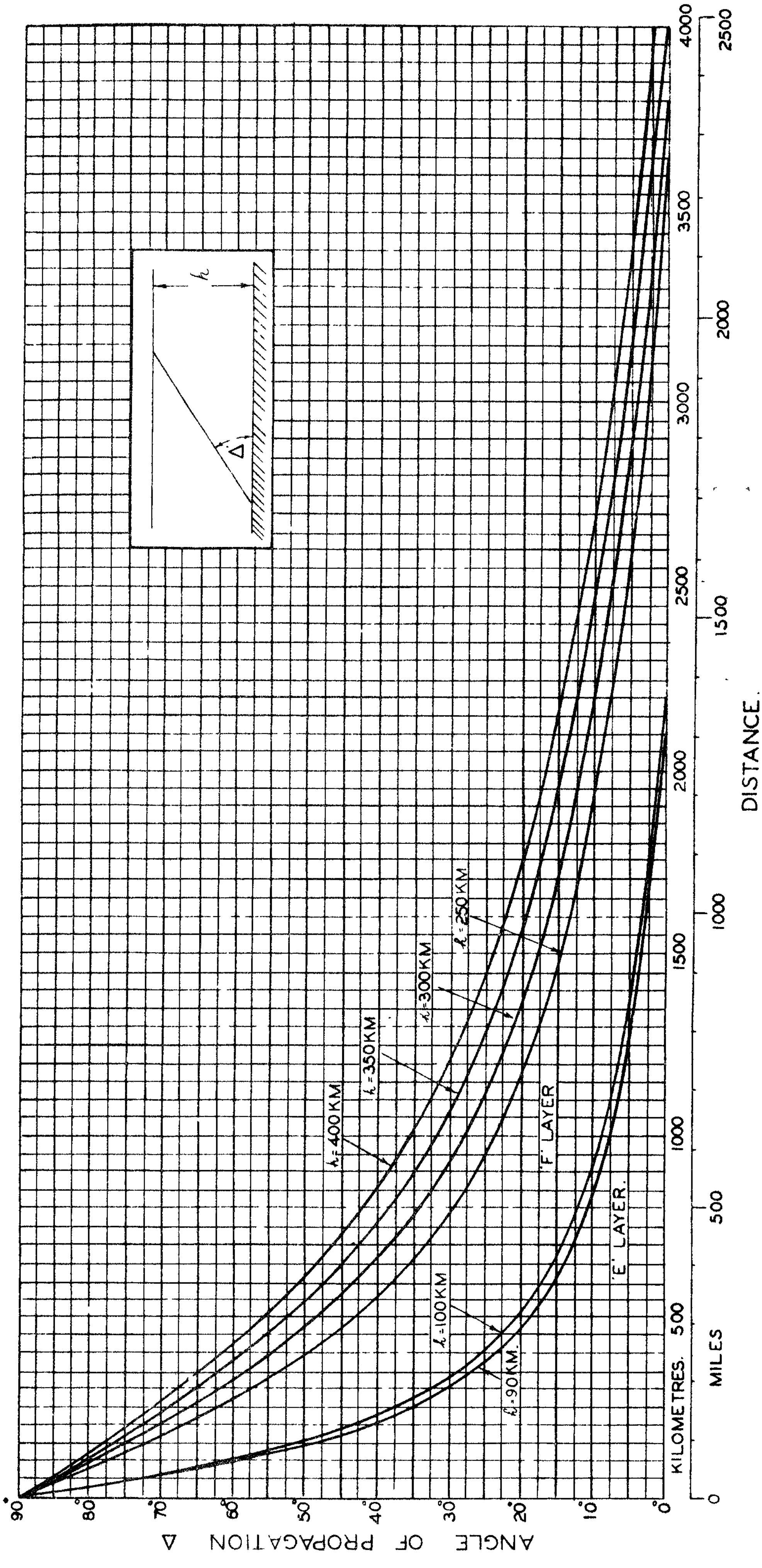


FIG. NO. 11.

TABLE I. PERCENTAGE ADDITIONS TO FREQUENCY TO ALLOW FOR SOLAR-CYCLE EFFECTS.

Year.	Latitude (N or S)					
	10°	20°	30°	40°	50°	60°
1942	2	4	6	8	10	12
1943	1	2	3	4	5	6
1944	0	0	0	0	0	0
1945	0	0	0	0	0	0
1946	1	2	3	4	5	6
1947	2	4	6	8	10	12
1948	3	6	9	12	15	18
1949	4	8	12	16	20	24
1950	5	10	15	20	25	30
1951	4	8	12	16	20	24
1952	3	6	9	12	15	18

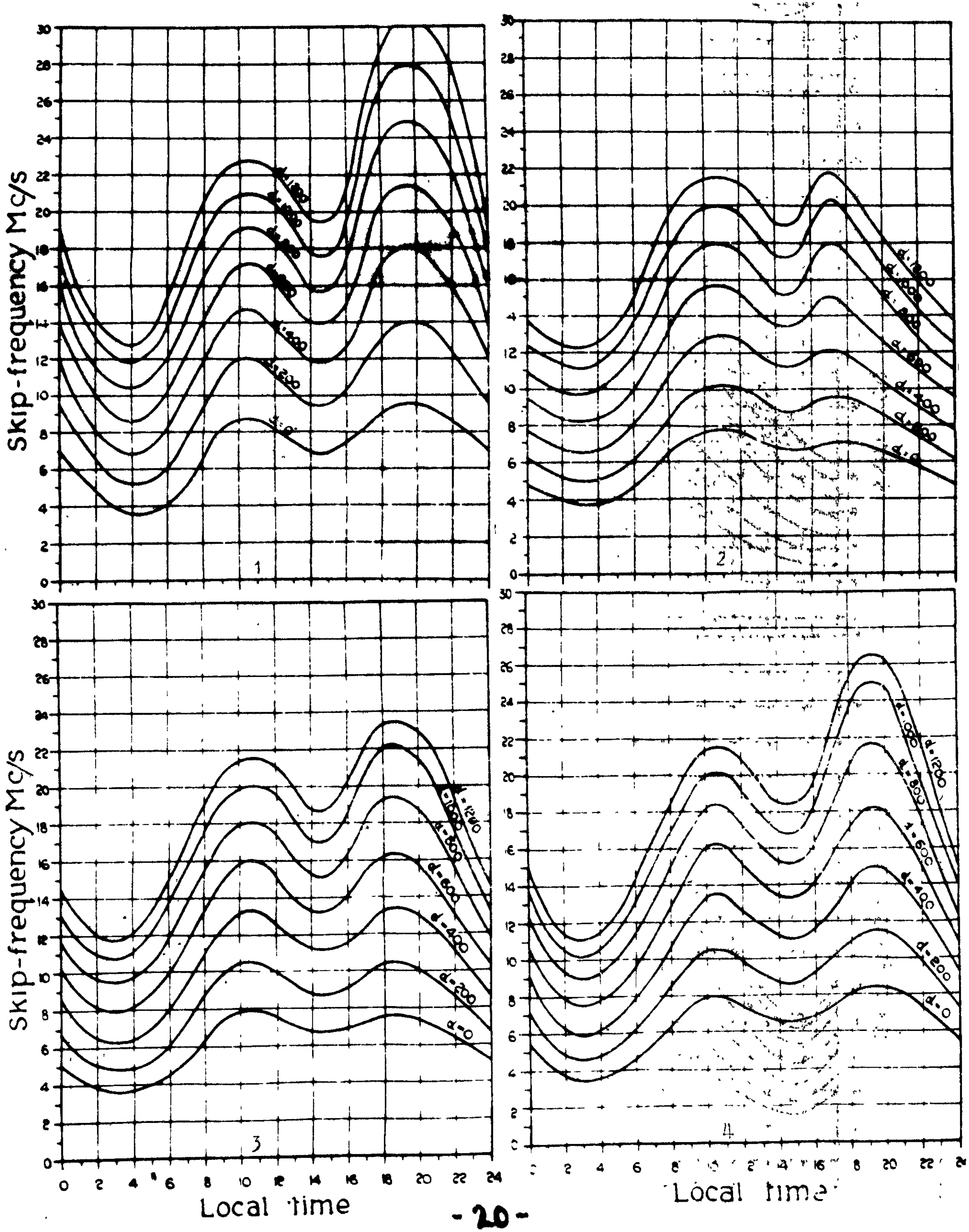
(ii) When using the curves of Fig. 12 it will be seen that the lowest line is marked d = 0, this means that the frequency shown against the time being considered is the critical frequency, i.e. the highest frequency which is returned to the earth after vertical projection. Thus, for this frequency and all below it, there is no skip area between the end of the ground wave and the beginning of the sky wave, conditions being those of curve B, Fig. 4.

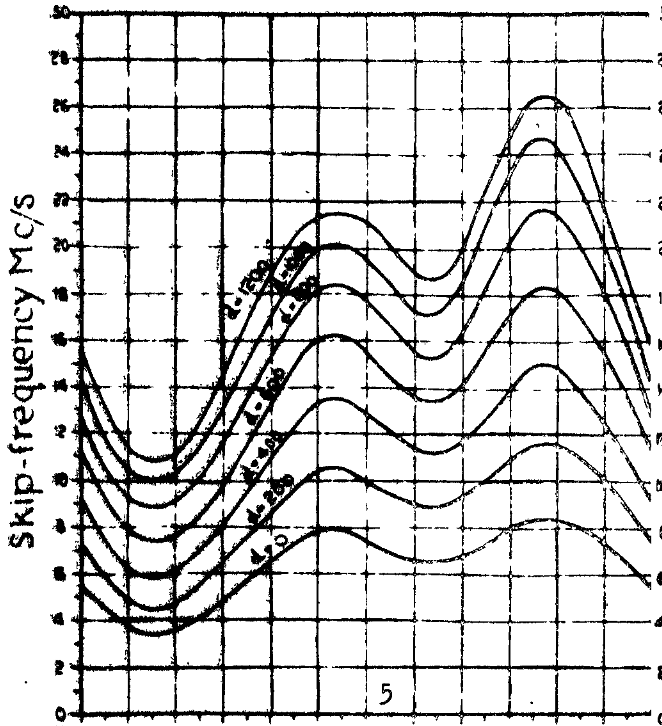
Fig. 12 Skip-Distance/Frequency Graphs.

(1) The graphs below are calculated for the minimum period of a sun-spot cycle, and the correction factors of Table I must be applied for other periods.

(2). The appropriate graph number for any latitude and month is given in the following table. The range "d" is in miles.

Hemisphere		Lat 15°N. to 15°S	Lat. 15° to 25° N or S.	Lat. 25° to 35° N or S.	Lat. 35° to 45° N or S.	Lat. 45° to 55° N or S.	Lat. 55° to 65° N or S.
Northern	Southern.						
Jan, Nov, Dec.	May, June, Jul.	1	2	7	12	17	22
Feb. Oct.	April, Aug.	1	3	8	13	18	23
March, Sept.	March, Sept.	1	4	9	14	19	24
April, Aug.	Feb. Oct.	1	5	10	15	20	25
May, June, Jul.	Jan, Nov, Dec.	1	6	11	16	21	26





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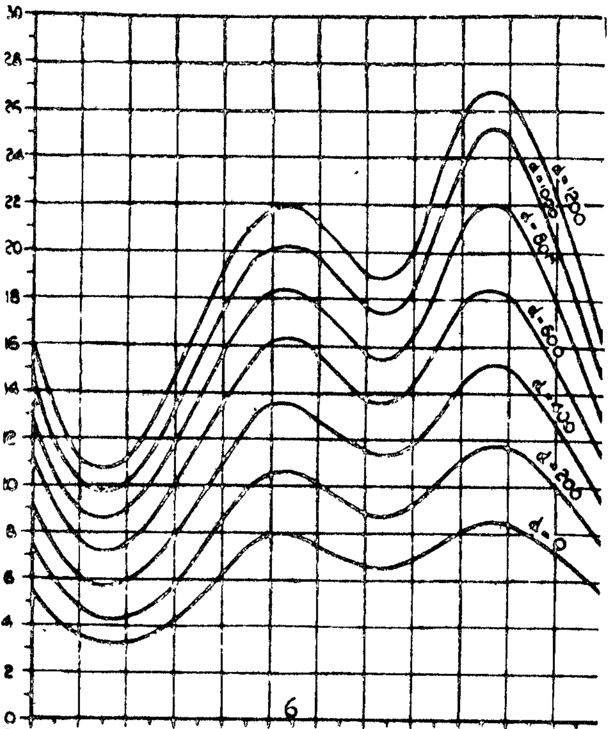

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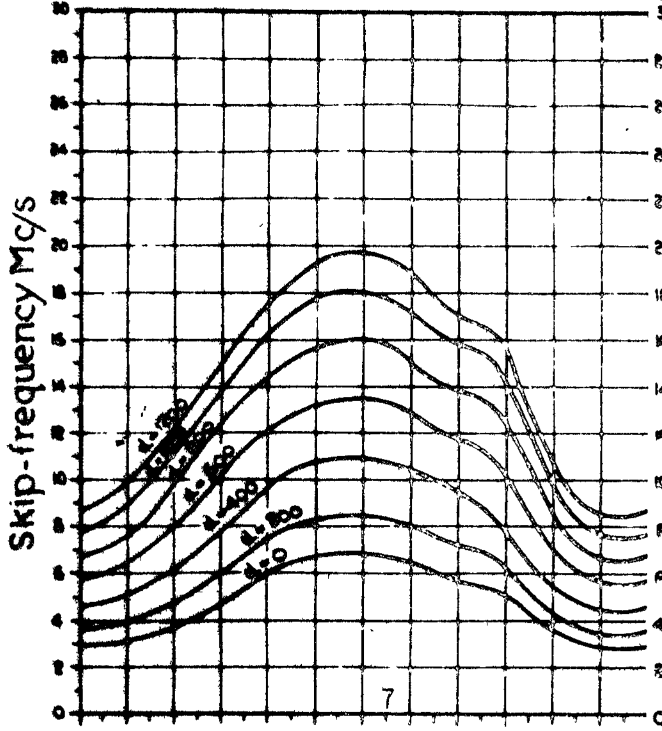

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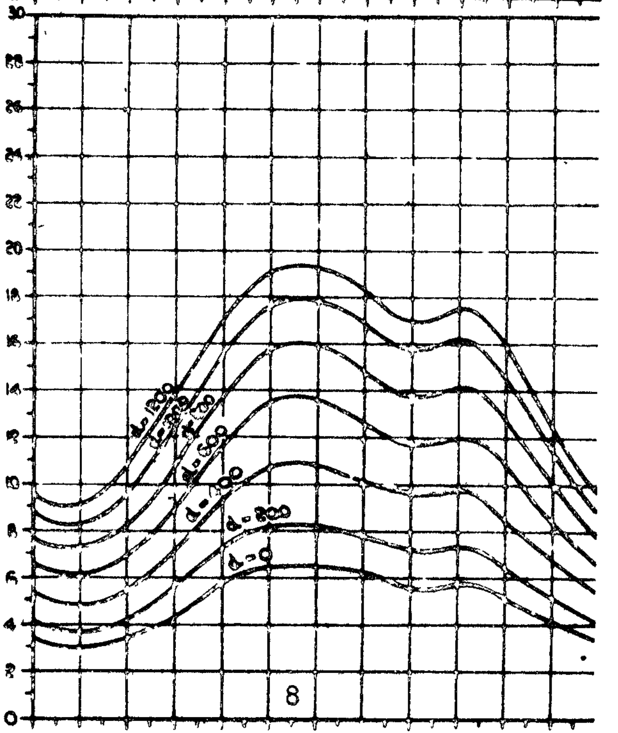

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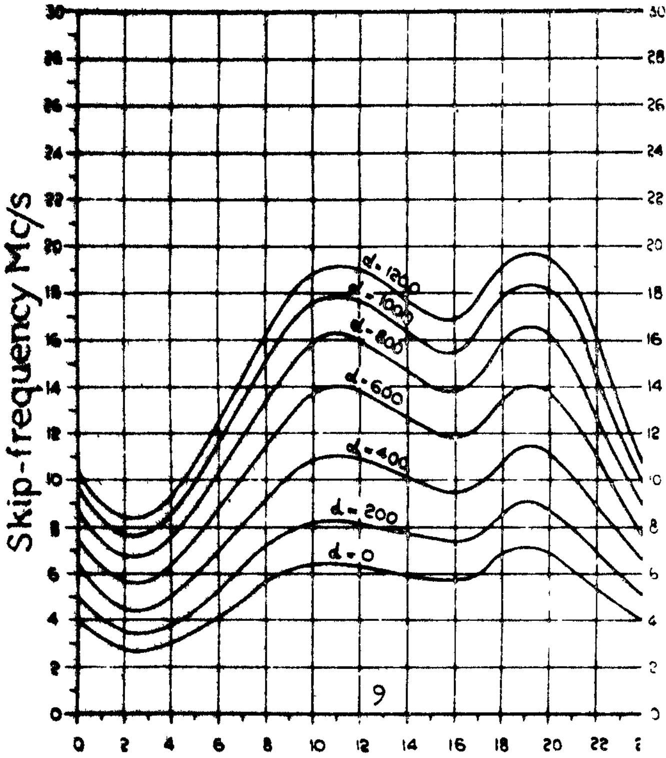

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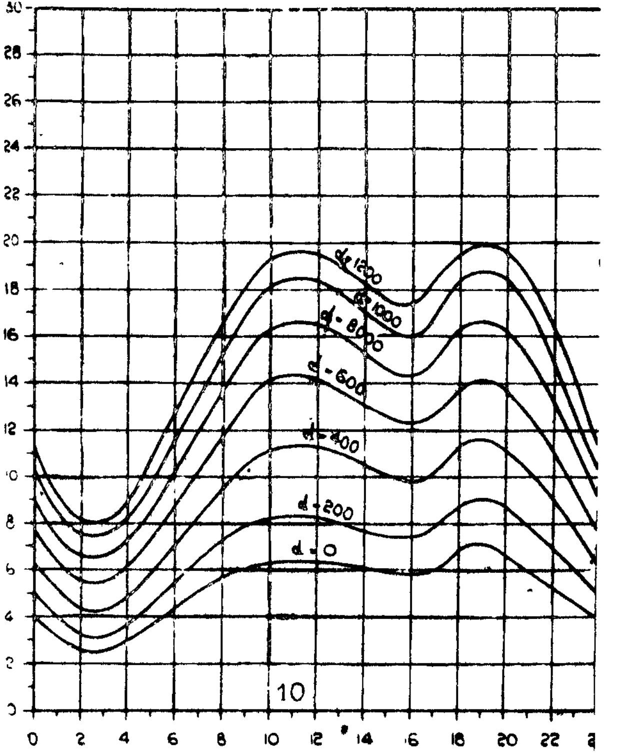

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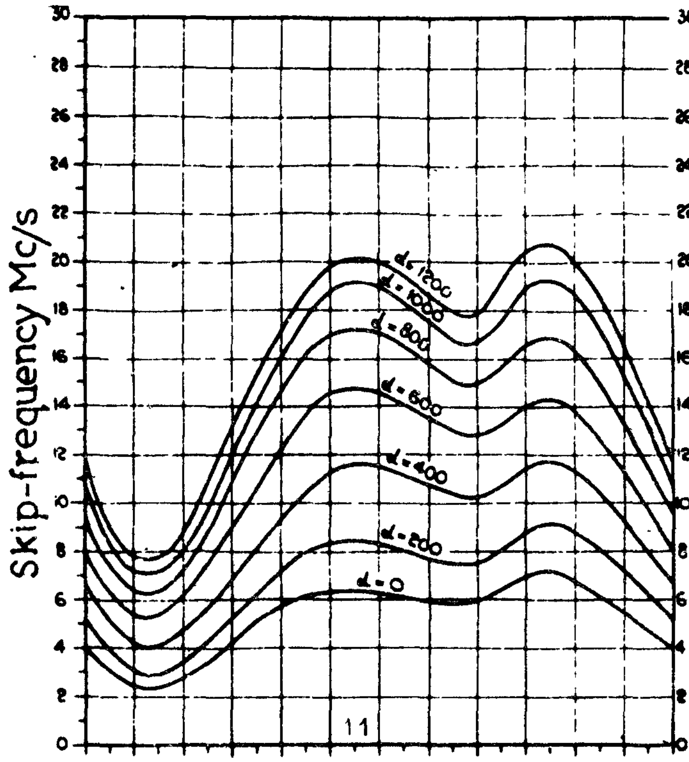
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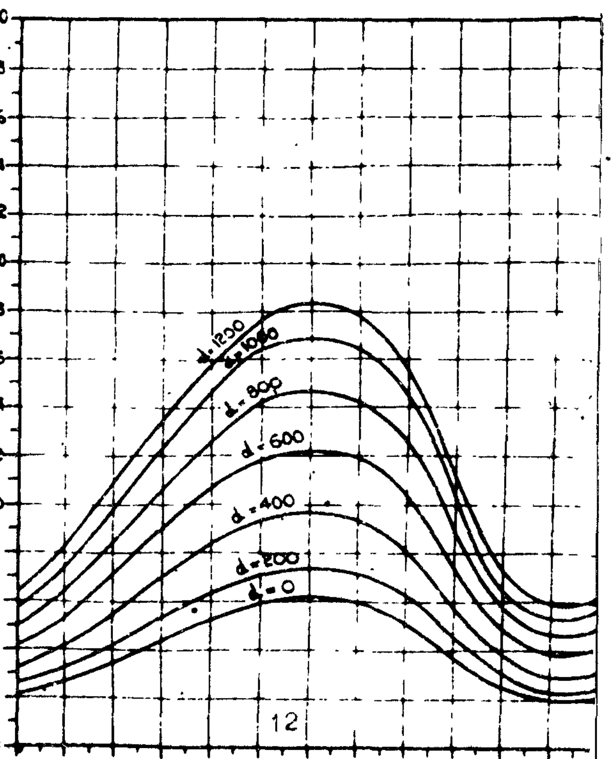
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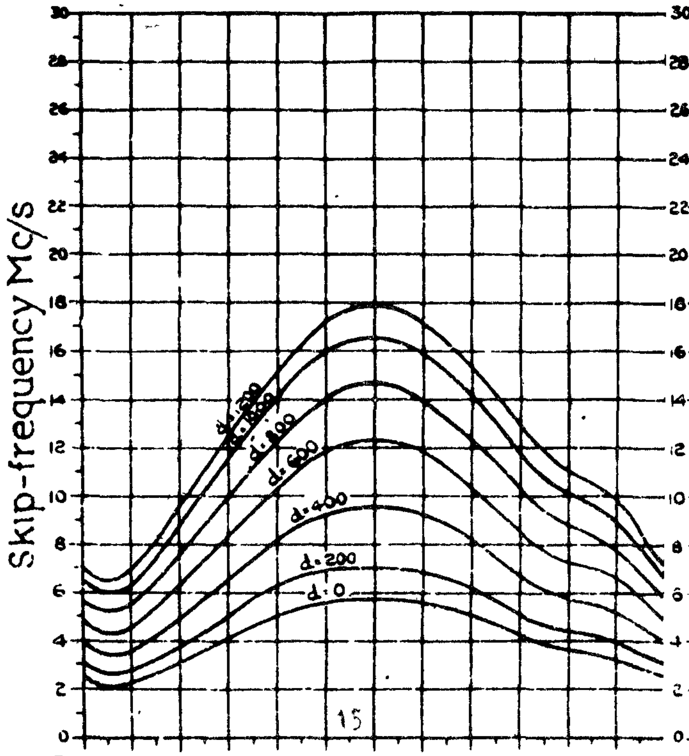
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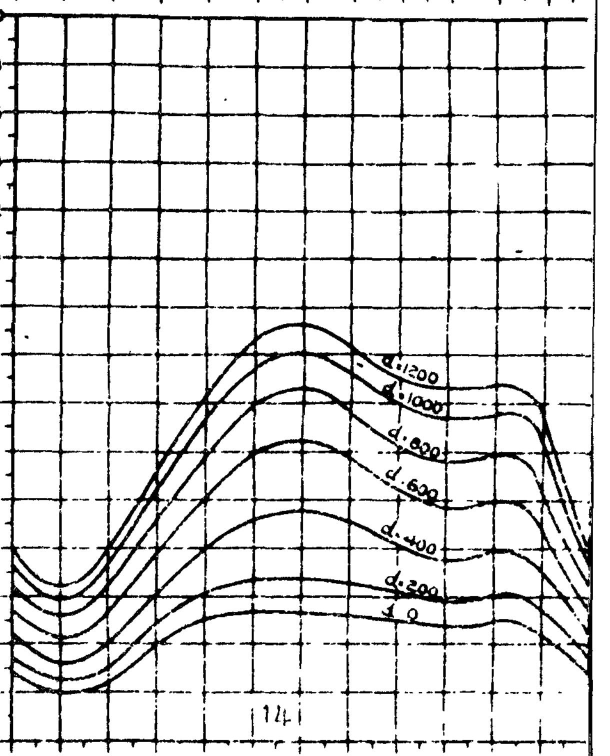
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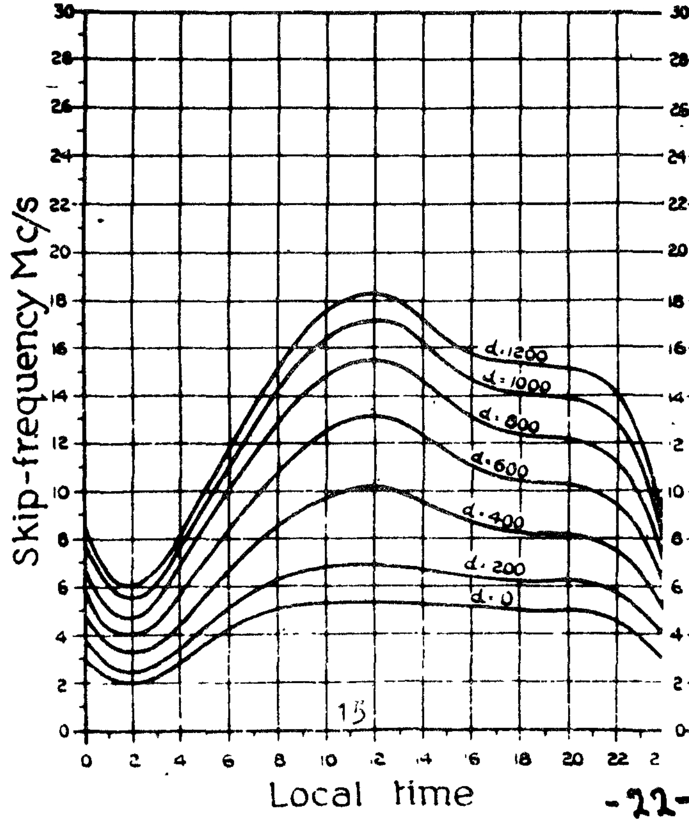
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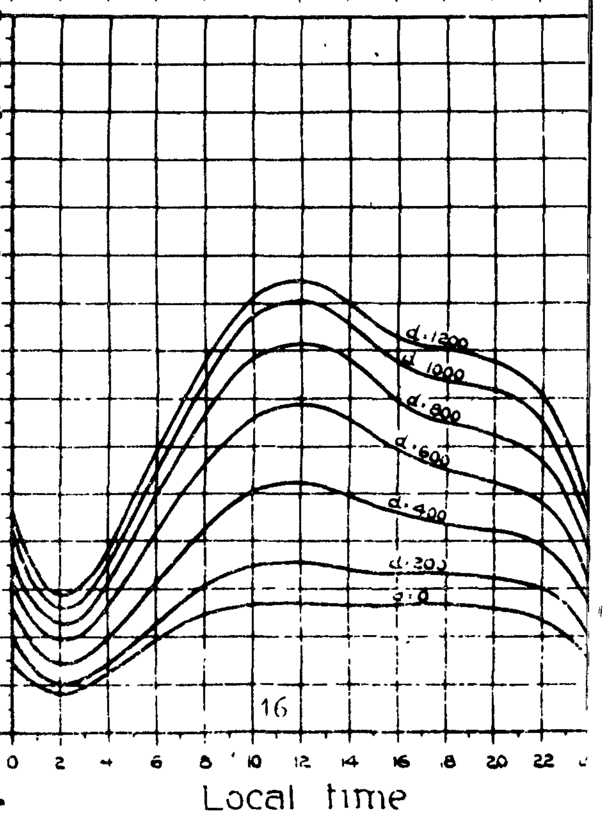
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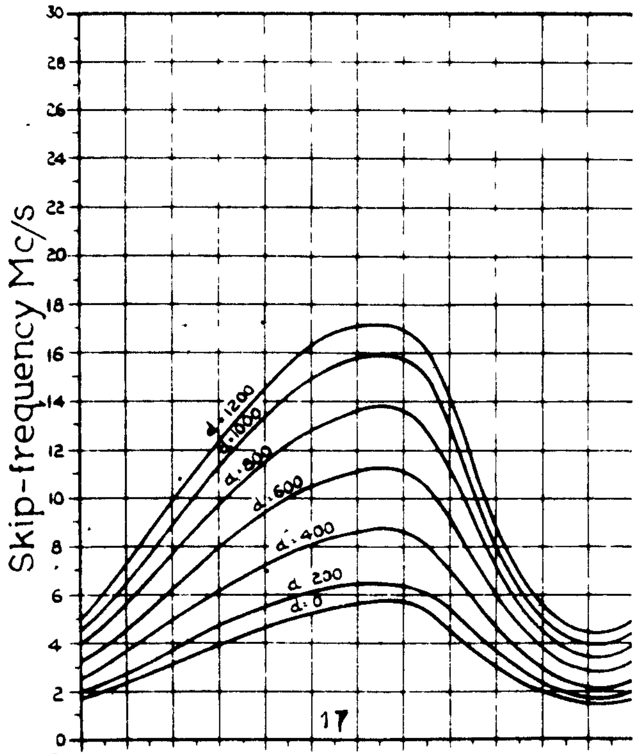
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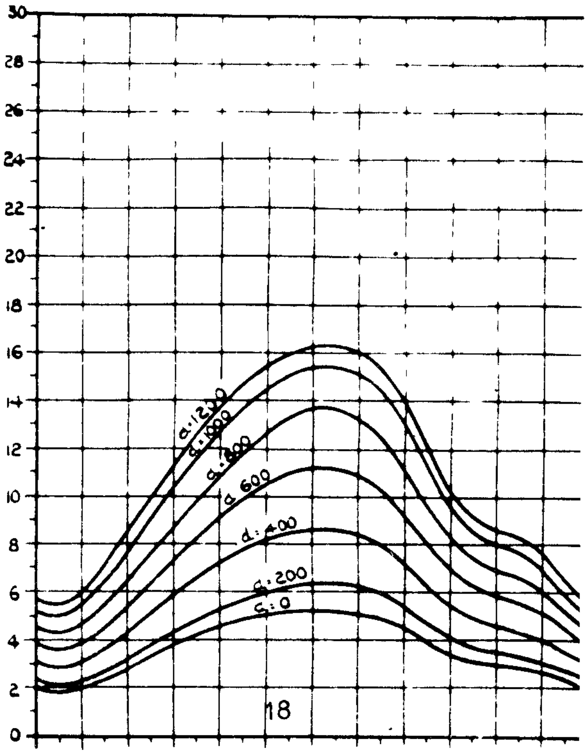
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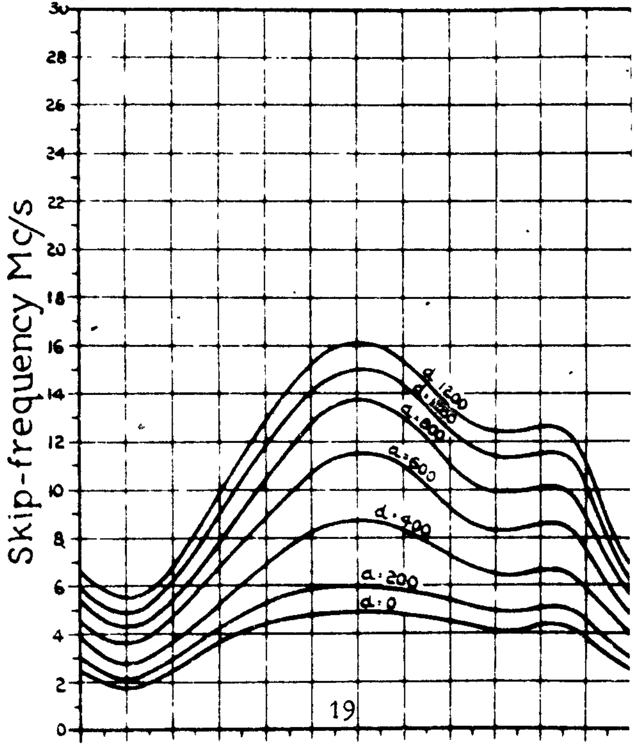
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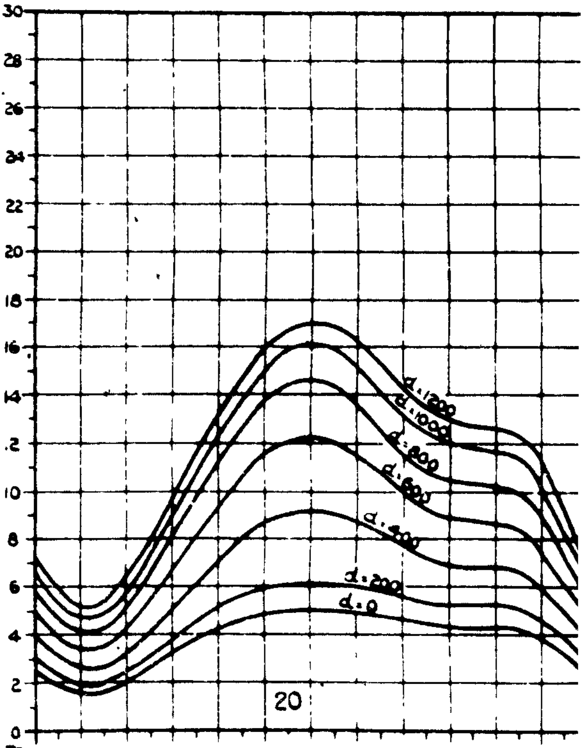
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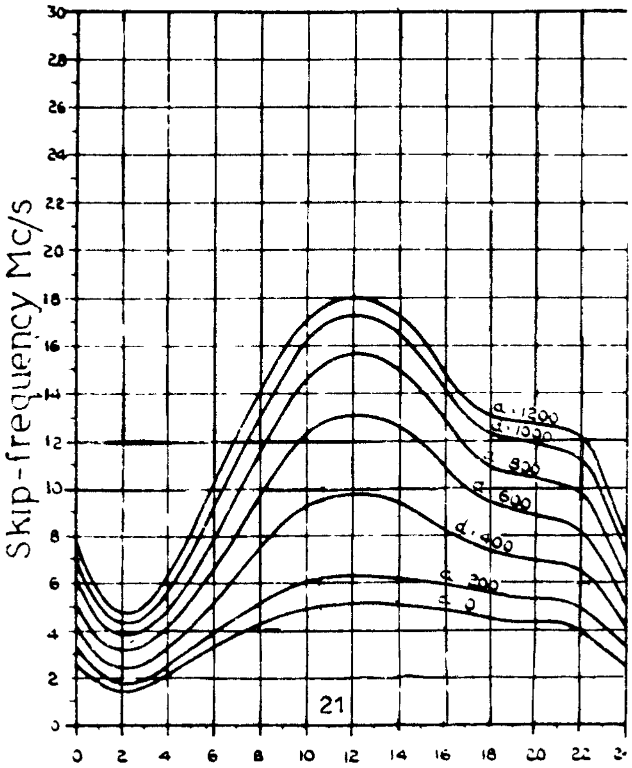
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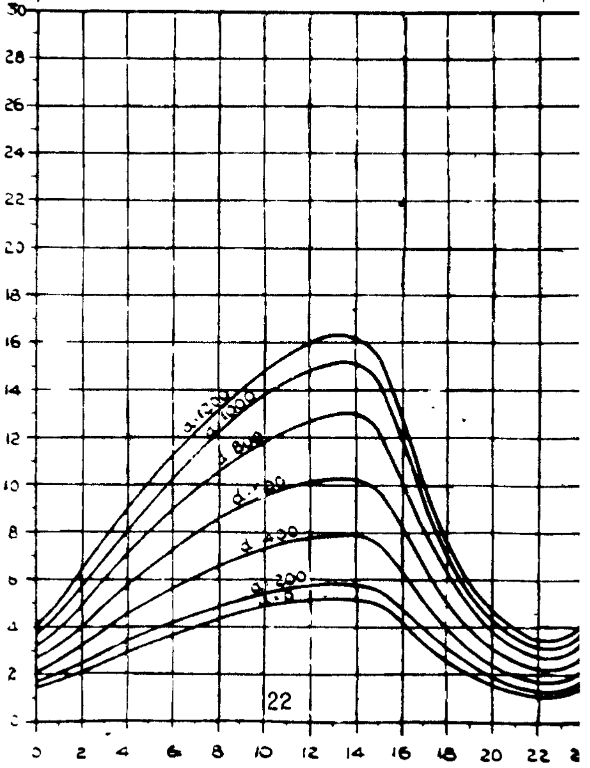
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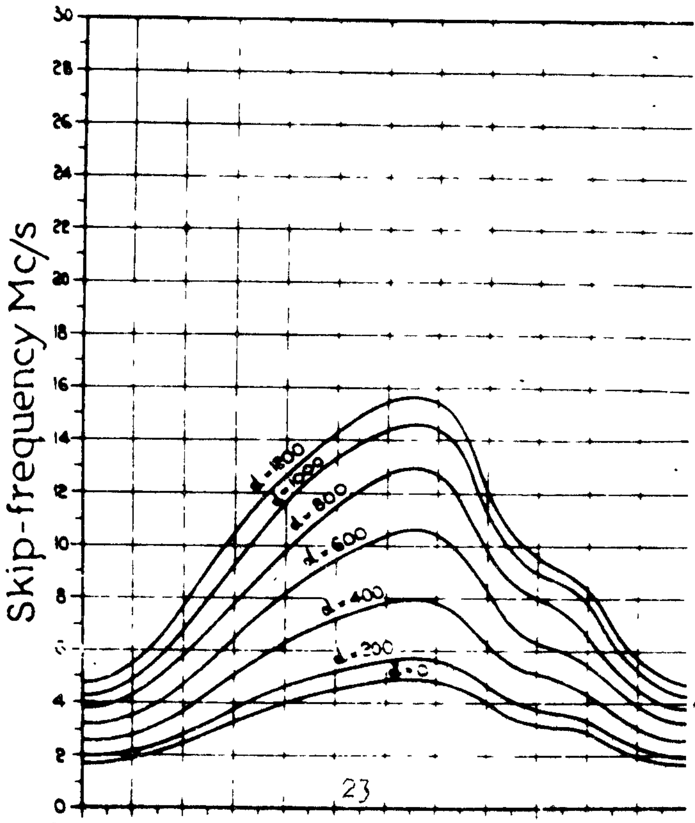
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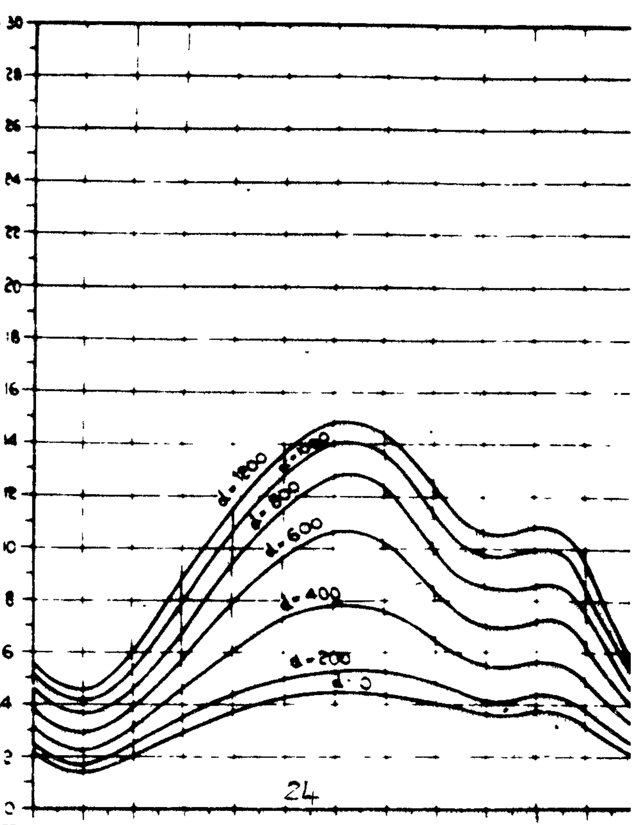
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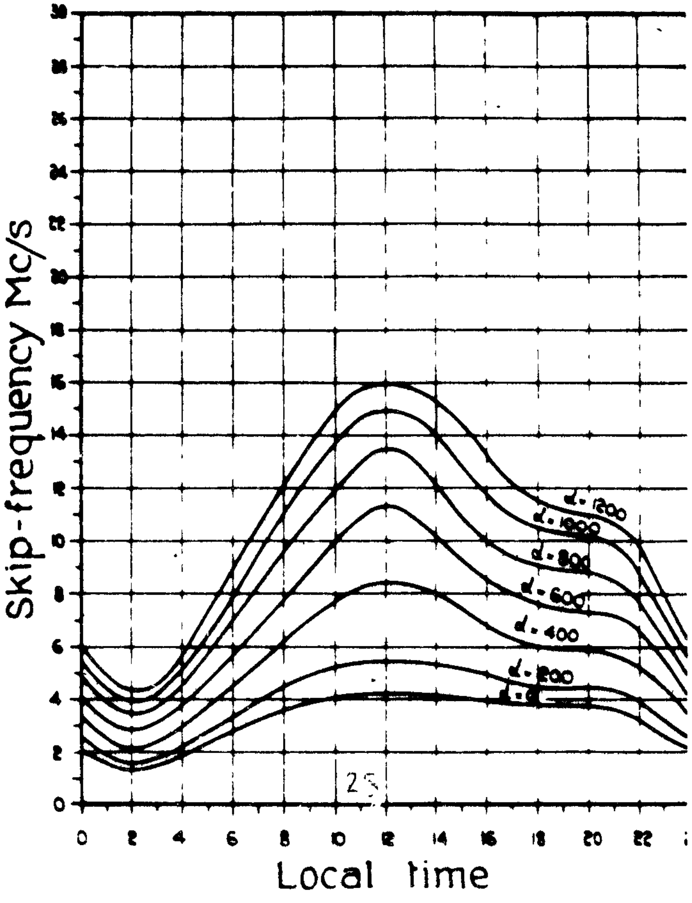
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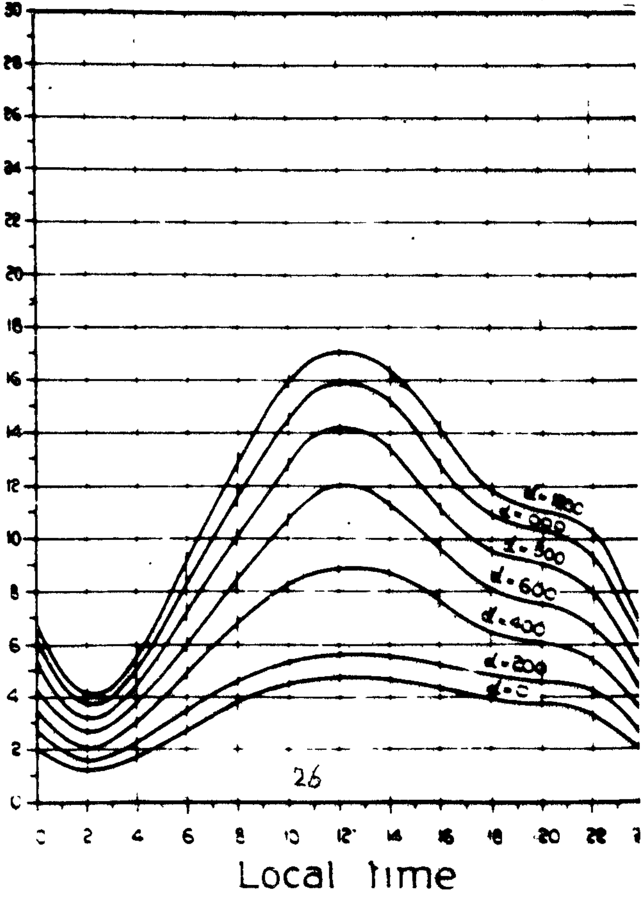
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CHAPTER 2.

Aerials.

1. (i) When a current flows along a straight conductor in free space, there is associated with it a magnetic field, whose lines of force travel in concentric circles, occupying the space in a coaxial cylinder of theoretically infinite diameter. At the same time there is an electrostatic field between the wire ends due to the potential difference between them; at the centre this field is parallel with the wire and also extends to infinity. These lines of force are at right angles to the magnetic field as shown in Fig. 13a.

(ii) If the current is alternating, both magnetic and electrostatic fields change in sympathy, the energy involved in creating the fields during growth of current and voltage being returned to the wire as the fields die away on reversal. This is true, however, only for low frequencies, for as the frequency is raised, more and more of the energy fails to return to the wire and is radiated into space as electromagnetic waves.

(iii) This loss of energy represents a load on the wire and can be regarded as a resistance when referred to the wire, this resistance is called the radiation resistance of the wire. The measure of the wire's ability to produce a magnetic field is its inductance, and an electrostatic field, its capacity. The square root of the ratio of these values gives the characteristic impedance of the wire. When the length of the wire is such that it is a half wave length long electrically, it resonates on its own as does a tuned circuit and is called a dipole.

(iv) The resonance of a half wave wire may be more easily visualized by supposing a small group of electrons dropped on to the near end of the wire one per cycle at its natural frequency. This electronic group has a negative potential. The moment they touch the wire the average potential of the wire will be lowered, the far end appearing positive to them; thus a flow of electrons will immediately start towards that end, and this flow constitutes a current, having its maximum intensity at the centre, the instant the charges at each end reach equal values, i.e. at the instant the potential is the same all along the wire. The wire thus has no effective potential, the energy of the electrons being now stored in kinetic form in the current flowing and the magnetic field associated with it. Fig. 13b illustrates this condition.

(v) As electrons pile up at the far end, as they must do having nowhere else to go, they will repel oncoming electrons more and more strongly, the negative charge accumulating until the current is finally stopped. At this instant the energy of the electrons is stored as a negative potential at the far end of the wire, i.e. the charges are now reversed and the cycle has passed through 180°. The current surge will now begin again and at 270° will reach a maximum as before but in the opposite direction. At 360° the current will have stopped again, and conditions will be the same as at the start, except that some energy will be lost through radiation, and some in heat because the wire is not a perfect conductor. If the make-up charges are bigger than the losses this standing wave or oscillation of current and voltage will increase until all the energy supplied is used up.

(vi) In general the object of an aerial designer is to produce standing waves of this nature on the radiating elements of his aerial, so that radiation takes place in a known manner where required. A similar resonance may be obtained with a quarter wavelength of wire if one end is connected to a theoretically infinite conducting sheet placed perpendicular to the wire. The reflection from the sheet then produces

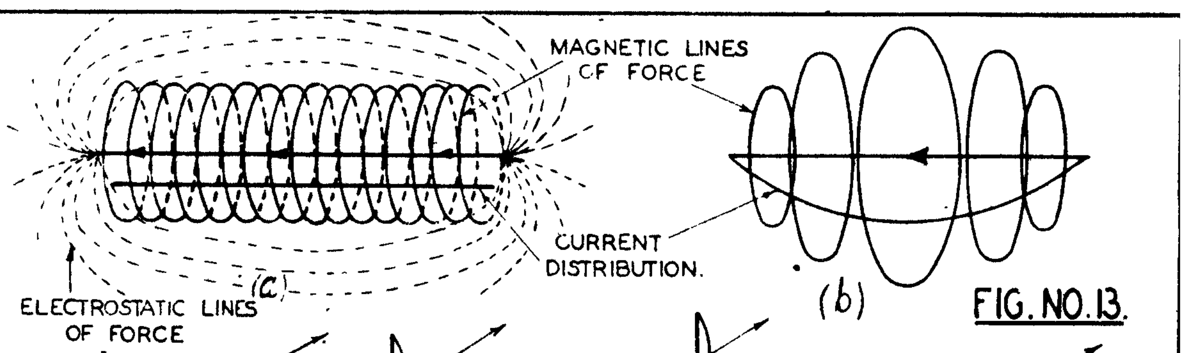


FIG. NO. 13.

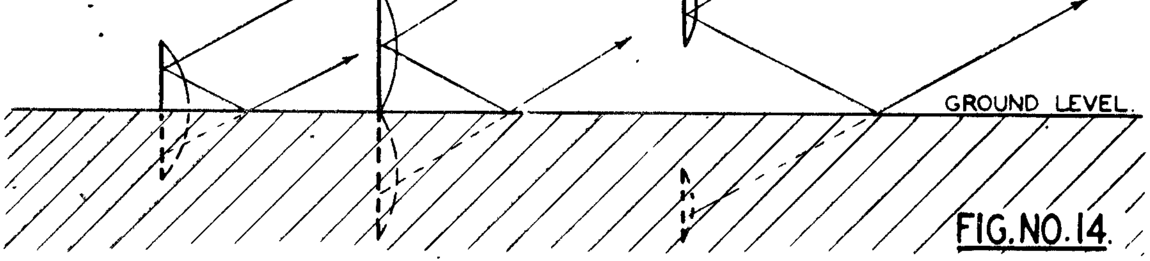
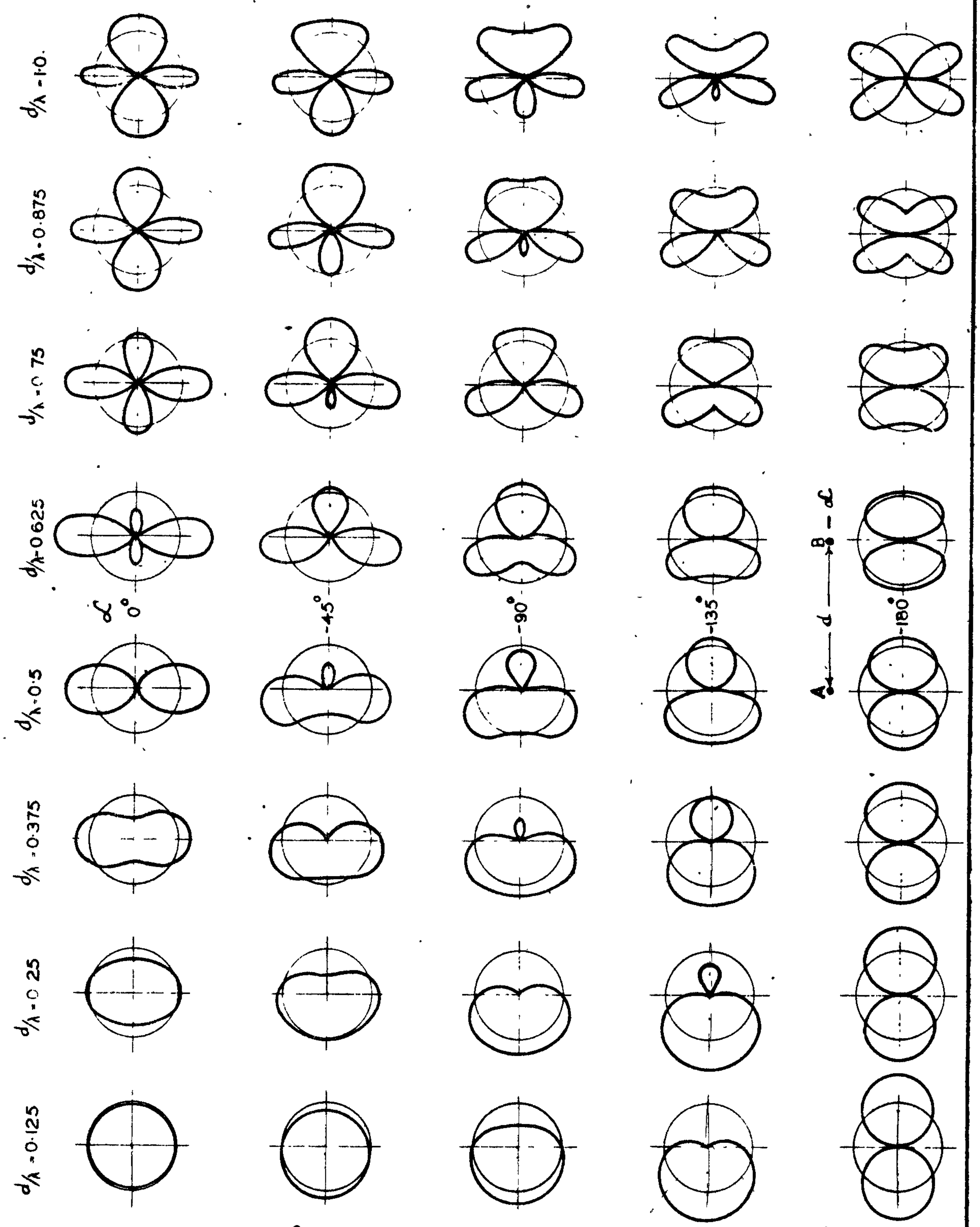


FIG. NO. 14.



α = PHASE ANGLE BETWEEN CURRENTS.

HORIZONTAL RADIATION PATTERNS FOR AN ARRAY OF TWO λ/4 ANTENNAS FED WITH EQUAL CURRENTS. FIG. NO. 15.

an image of the quarter wave wire, as say a pencil standing on a mirror appears to be carried on into the mirror, and the system resonates as freely as a half wave wire, but with halved radiation resistance. Fig. 14 shows this effect, which holds for all aerials though the mirror action of the earth is dulled by its fairly high resistance.

Aerial Characteristics.

2. (i) The simplest aerial, usually used for reception on low and medium frequencies, consists of a piece of wire of indefinite length, more or less vertically arranged and with the lower end connected to the aerial terminal of the receiver. Because its length is usually very small compared with the wave length, it is relatively inefficient and has a capacitative or negative reactance. The efficiency can be improved by tuning the aerial so that the system as a whole resonates, and this is done by connecting a coil between the lower end of the aerial and the earth. The inductance of the coil must be adjusted so that at the wanted frequency its positive reactance is equal to the negative reactance of the aerial capacity. These two reactances thus cancel out and the current in the aerial increases to the limit imposed by the resistance and the incoming power. The actual increase depends upon the magnification or "Q" of the circuit which is the ratio of the reactance/resistance.

(ii) As the inductive and capacitative reactance of this aerial are now fixed they are only equal at one frequency, so that enhanced operation at this frequency is obtained at the expense of frequency response or band width. Thus the reception of different frequencies by one aerial presents some complicated problems, and behind the aerial terminal on a receiver is the designer's compromise between the many conflicting factors.

(iii) The aerial described above is from the earth point a quarter wavelength long electrically (or an odd number of quarter wavelengths) and is the type originally used by Marconi for transmission and reception. The need for an earth connection distinguishes Marconi's aerial fundamentally from the Hertz or dipole aerial, which requires no "earth", and is balanced to it.

Directional Characteristics.

3. (i) As radiation leaving a wire depends on the electrostatic and electromagnetic fields, radiation does not leave equally strongly in all directions, so that every aerial has directional characteristics associated with it. For these characteristics to be used they must be known, and plotted as polar diagrams. Since space has three dimensions, diagrams in both vertical and horizontal planes are necessary, but as the radiation pattern is really a solid figure a model gives the only true picture and the use of vertical and horizontal diagrams needs some imagination.

(ii) The horizontal diagram of any single vertical aerial in clear surroundings is a circle, that is, it radiates equally well in all directions along the ground. By grouping aerials the radiated waves are made to interact upon one another, their fields cancelling in some directions and reinforcing in others. The exact directions in in which they cancel or reinforce, and how much, depends on the distance between the aerials and the relative phase and strength of their currents. Fig. 15 shows the horizontal polar diagrams of two vertical quarter wave aerials with different spacings and phase displacements, but with the same current in each aerial.

(iii) The condition of equal currents in Fig. 15 is not common in practice where the second element is often parasitically excited, with the result that the current in the second element will be lower and the resulting polar diagrams quite different. Fig. 16 shows these for various positions and tuning conditions of the parasitic element. It can be seen from Fig. 16 that the maximum gain in signal strength possible is nearly two, and this is shown plotted against spacing in Fig. 17 for both forward and backward radiation, i.e. with the parasitic element reflecting and directing respectively.

Changes in Tuning and Radiation Resistance.

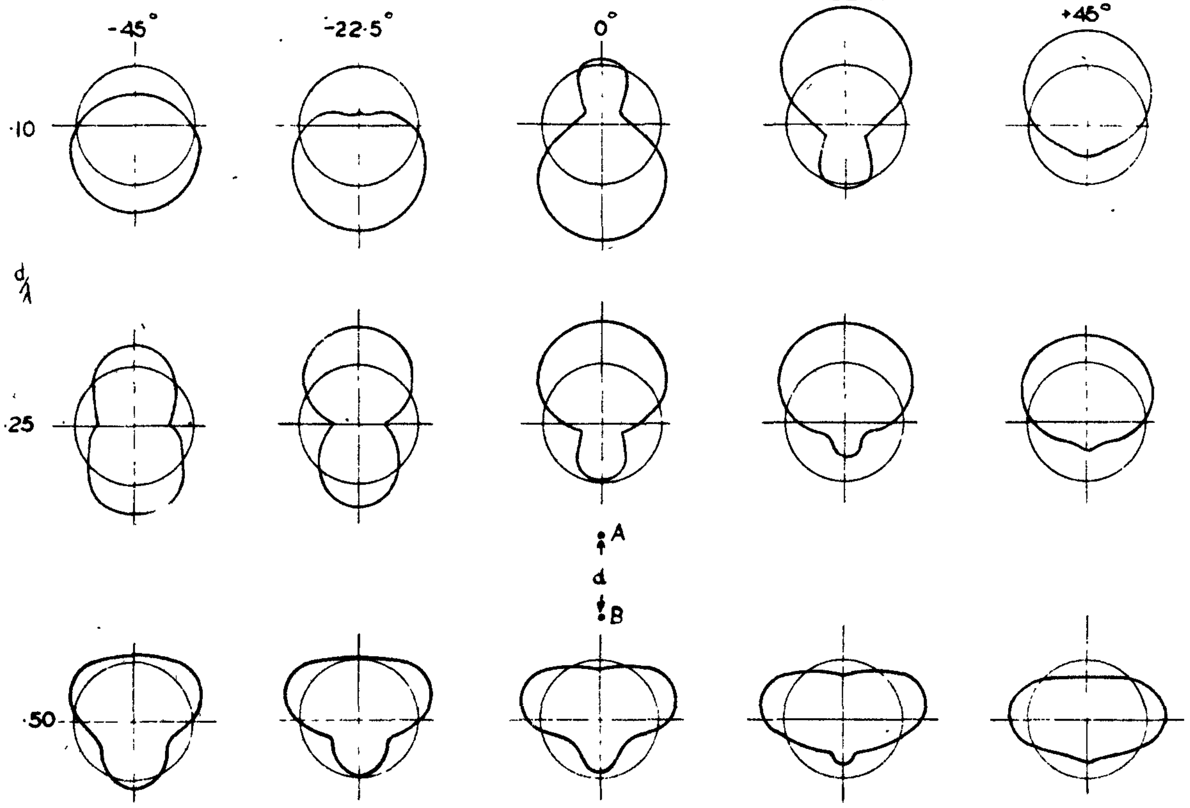
4. (i) The coupling between driven and parasitic elements causes the tuning to vary with the distance between them, and consequently whether a parasitic element reflects or directs will depend on both its spacing and initial tuning. At the same time as the tuning, i.e. the reactance, of both elements is altered, the radiation resistance of the driven element is also changed. These changes are shown in Fig. 17, 18, and 19.

(ii) The large fall in radiation resistance of the driven element as shown in Fig. 19 should be noted, as it indicates that a great increase in the sharpness of tuning of the aerial as a whole will take place, for the magnification "Q" has been increased by as much as nine times. This means that the frequency response or tolerance is much poorer. It also means that when used as a directive array for transmission or reception impedance matching arrangements will be quite different, and that unless adjusted to the new condition, the addition of a director or reflector may not be worthwhile, for as a result of the mismatch increased currents and voltages in the cable will cause greater losses, and the transmitter will probably be incapable of developing full power into such a heavily reactive load. In the receiving case the loss will not be so great for there will be no additional cable losses, and as an increase in signal/noise ratio is usually the main object the reduction in random noise, due to the discrimination of the new polar diagram, may give a reasonable improvement. The previous remarks on frequency tolerance will still apply so that even if accurately matched a frequency variation of ± 2% will reintroduce a 2 : 1 mismatch. Thus, unless the frequency is quite definite little is to be gained.

Directional Characteristics (cont.)

5. (i) So far only horizontal diagrams have been considered. In the vertical plane the angles at which radiation leaves depends upon the height of the aerial, its current distribution, and if the aerial is directive, the plane in which we are interested. Fig. 20 (a-d) shows the vertical diagrams for 1/6th, 1/4, 1/4 inverted, and half wave vertical aerials. All these have only one main lobe of radiation, but for grounded vertical aerials of greater height secondary lobes appear at high angles, and Fig. 10 (e-h) shows diagrams for aerials of .56, 5/8th, 3/4 and one wavelength. As the length is still further increased the main lobe of radiation slowly becomes more nearly vertical though never actually so, and aerials such as these are useless except for special applications as the ray travels outward only a short distance per hop and is soon lost. In the case of directive vertical aerials the general shape of the polar curve will be much the same in all vertical planes, but its strength will vary with the horizontal diagram.

(ii) As mentioned in paragraph 3 (i) the complete polar diagrams of any aerial is a solid figure. For the aerials of Fig. 20 the solid figure is that for which the diagrams are half cross sections; i.e. with the wire as axis, rotation of the diagram will produce this solid figure. For a half wave dipole in free space the solid figure



THE HORIZONTAL RADIATION PATTERNS OF AN ANTENNA AND A SINGLE REFLECTOR FOR A NUMBER OF SPACINGS AND TUNING CONDITIONS.

FIG. NO. 16.

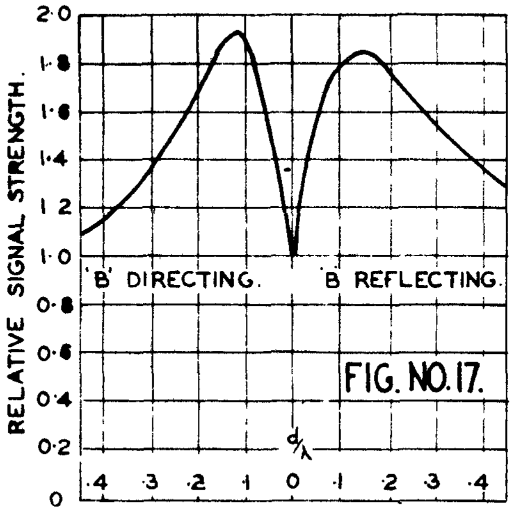
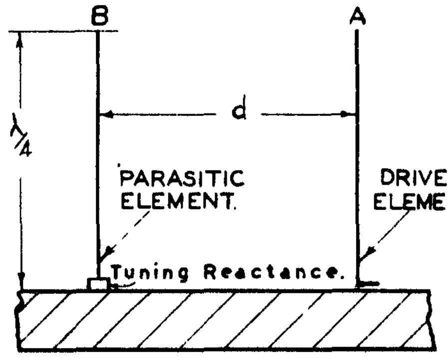


FIG. NO. 17.

THE INCREASE IN FORWARD OR BACKWARD SIGNAL WITH DIFFERENT SPACINGS BETWEEN 'A' & 'B'.



'B', REFLECTING FORWARD SIGNAL →
'B', DIRECTING BACKWARD SIGNAL ←

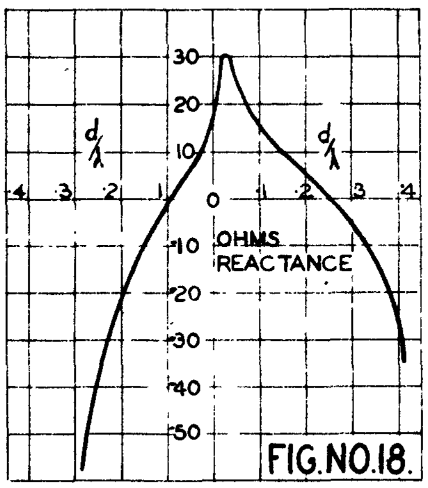


FIG. NO. 18.

THE TUNING CONDITION OF 'B' FOR MAX. FORWARD OR BACK-WARD RADIATION

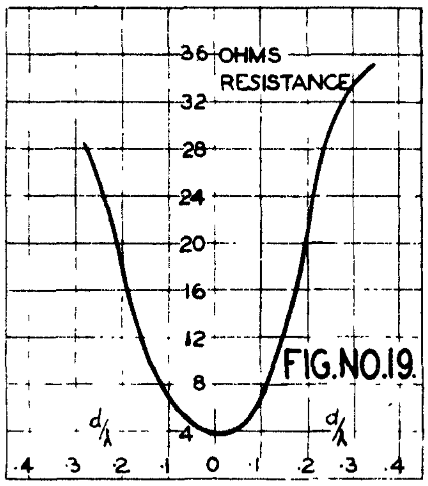


FIG. NO. 19.

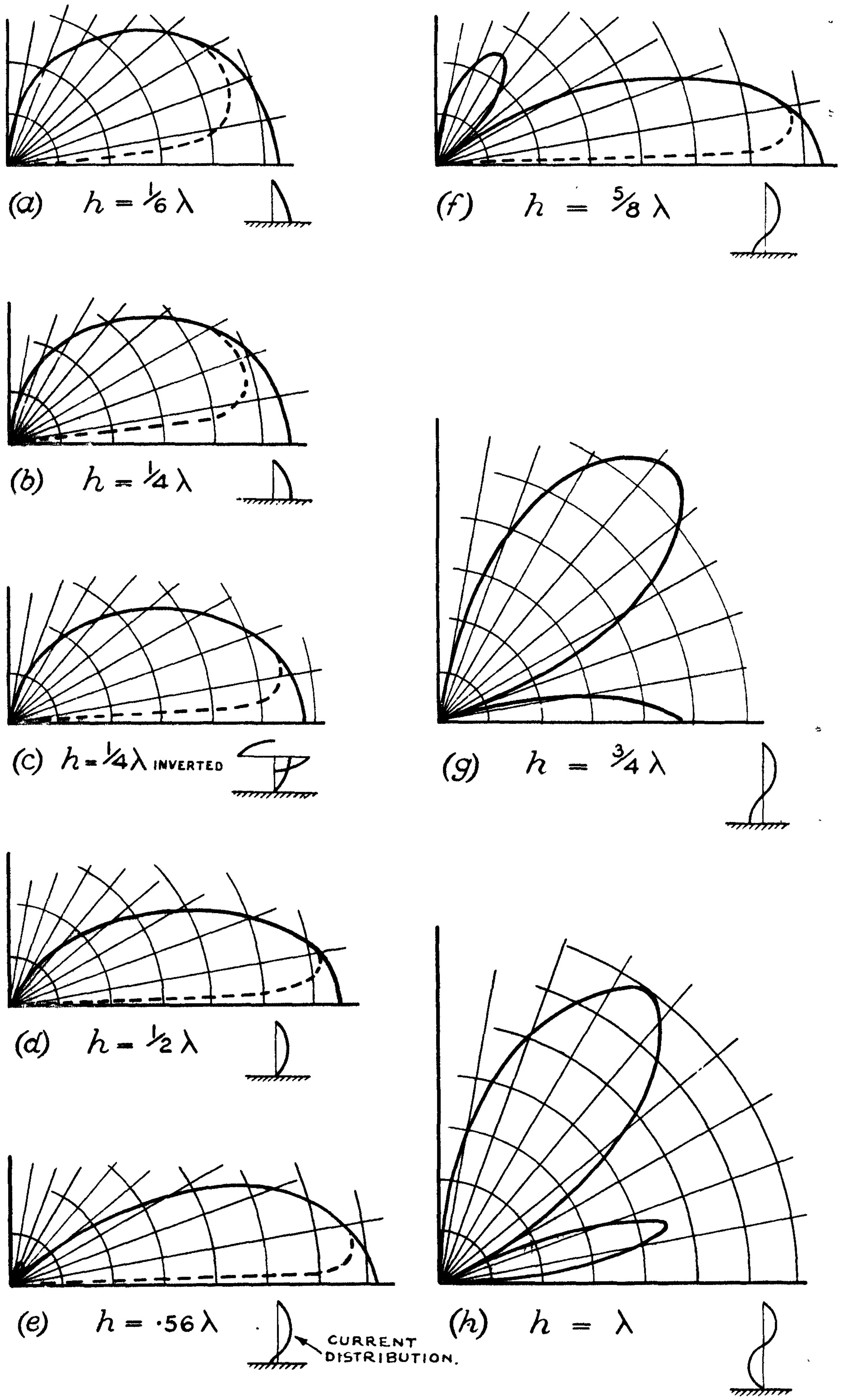
THE RADIATION RESISTANCE OF 'A' WHEN 'B' IS ADJUSTED FOR MAX. FORWARD OR BACKWARD RADIATION.

resembles a toroid, or spherical balloon, squeezed at two polar points until the opposite sides touch, the wire of the aerial lying along the direction of pressure. Fig. 21 is a representation of this. If a plane ABCD is made to cut the figure as shown and the part below the plane neglected, the resulting solid diagram is recognised as that of the quarter wave vertical aerial Fig. 20B. Also if another plane EFGH is passed through the figure perpendicular to ABCD the resulting pattern on this plane is the familiar figure of eight, the horizontal diagram of a half-wave horizontal dipole. If now, this plane is moved away from the wire while still remaining parallel, it can be regarded as a reflecting sheet, and radiation from the wire will be reflected back to the wire or outwards depending on the angle of incidence on the plane. As the distance is increased, the relative phase angle between direct and reflected waves will vary, causing cancellation and addition in different directions. The cross section of the solid figure resulting from this will be on the plane ABCD and because of this reflection, will no longer be circular. The exact shape of this figure will depend on the distance between the wire and the plane. These figures are shown in Fig. 22 and are the vertical diagrams of a horizontal dipole at varying heights above earth. On the plane EFGH the pattern will remain a figure of eight as long as the wire is a half wave length, but if the wire length is increased interaction between waves radiated from various parts of it which are out of phase will greatly alter this pattern. Fig. 23 shows the horizontal patterns for aerials varying in length from .5 to 2 wavelengths. As these patterns are independent of the height the aerials may be above ground, the vertical patterns of Fig. 22 will still apply.

Arrays of Dipoles.

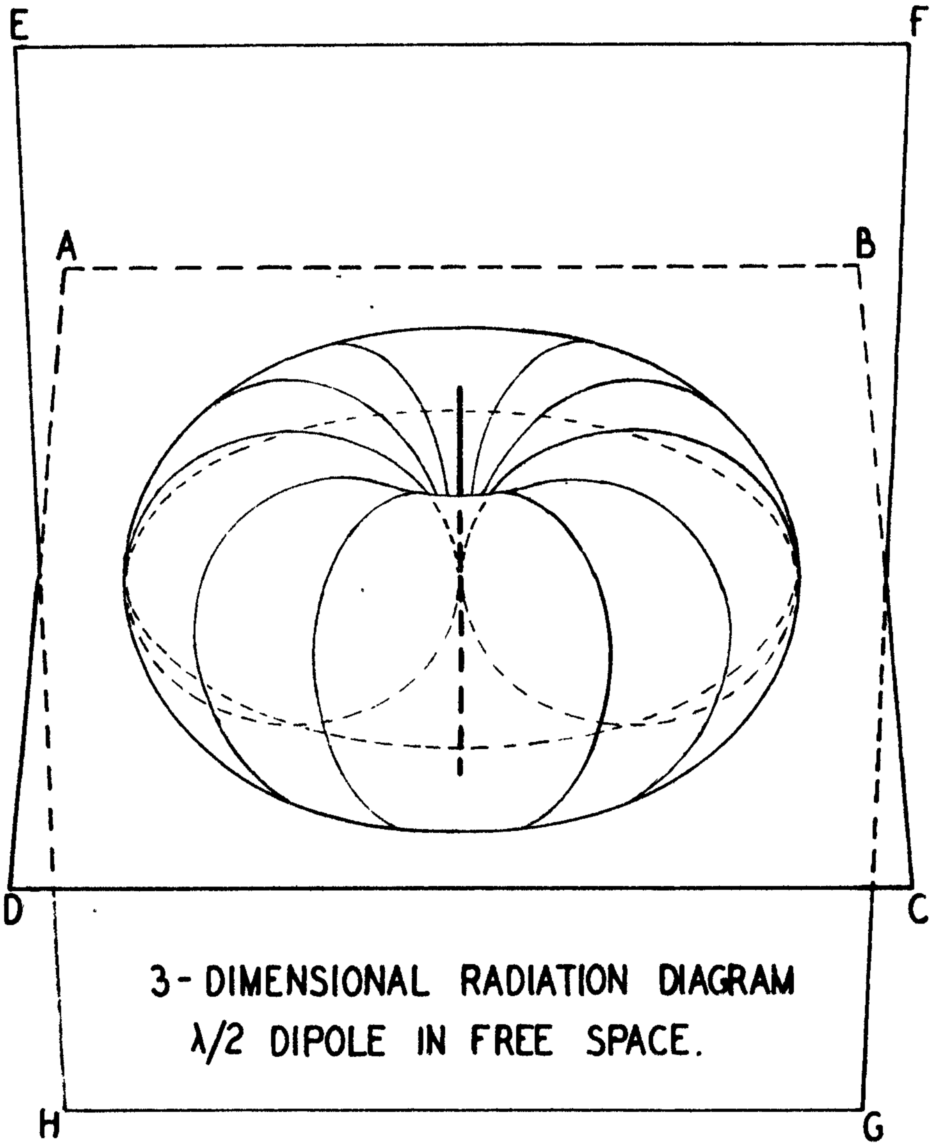
6. (i) As with the vertical aerials mentioned in paragraph 3 horizontal aerials may also be grouped, and they may be arranged vertically in tiers and horizontally in bays. The simplest of these arrangements, known as stacked dipoles or Koomans arrays, which gives a gain over the horizontal dipole, is the 1 bay 1 tier Koomans which is two half-wave elements placed end to end and fed at the centre so that the currents in the two half waves are in phase. Radiation from these two elements will, therefore, add in a forward and backward direction at right angles to the axis of the wire, and the field strength is increased by a narrowing of the arc over which the power being radiated is distributed. This process can be continued by increasing the horizontal width of the aerial or array, and Fig. 24 shows the increasing field strength in the desired direction and the narrowing arc of radiation for aerials having various numbers of elements. It has been seen from Fig. 20 that a horizontal aerial, half wavelength above ground, produces a single lobe of radiation at 30° above the horizontal. This angle, which is too high for long distance communication (the distance per hop is too short), can be reduced by increasing the vertical height of the aerial or array, i.e. by arranging tiers of elements all fed in phase, so that their radiation produces a narrow lobe in the vertical plane in a similar manner to that produced by increased horizontal width in the horizontal plane. Fig. 25 shows the vertical polar diagrams of arrays of various numbers of tiers. There are many ways by which the radiating elements can be fed so that radiation takes place in desired directions and many aerials have been designed. Fig. 26 shows current distributions and feeding arrangements for the following aerials:-

(a) Stacked Dipoles or Koomans Arrays.
(b) Colinear dipoles.
(c) Horizontal Sterba.
(d) Vertical Sterba.
(e) Franklin Uniform.



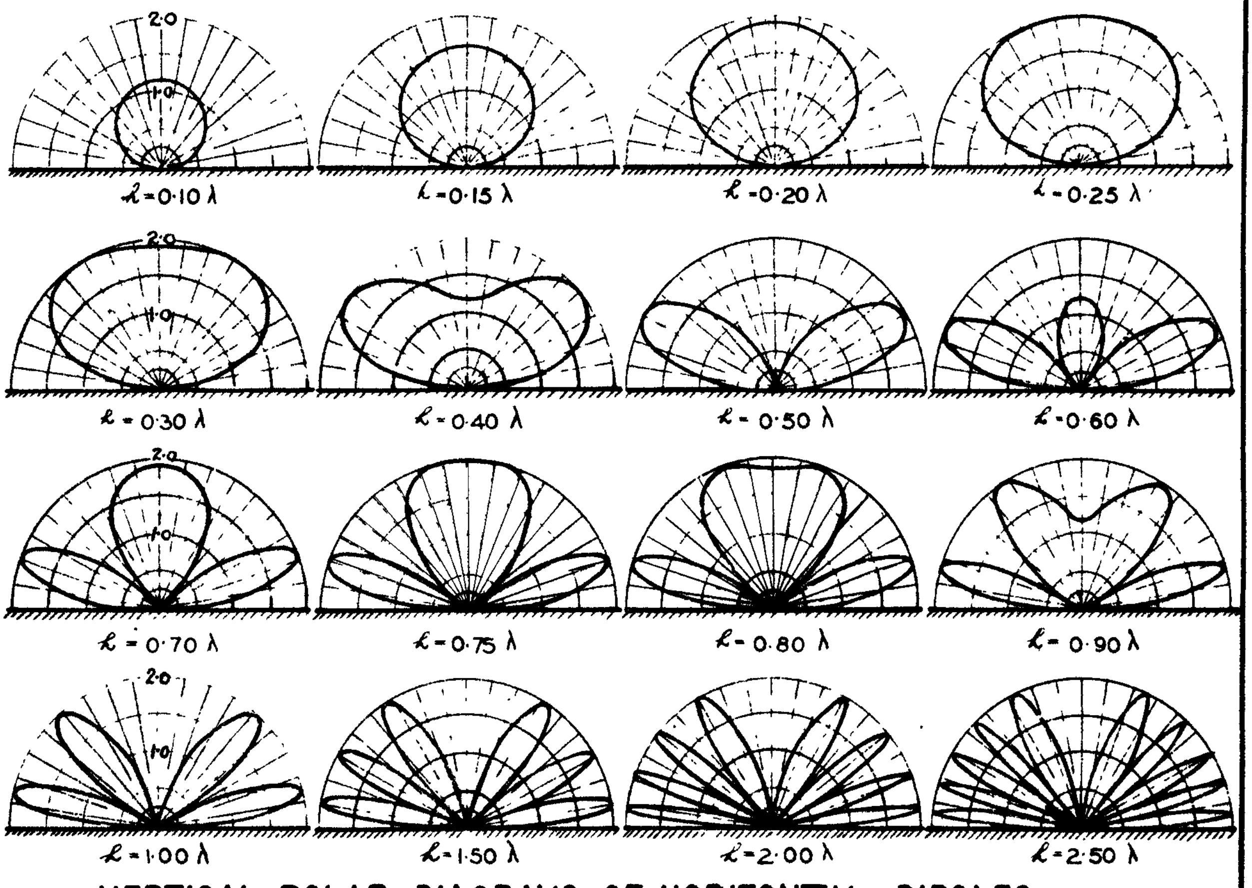
VERTICAL POLAR DIAGRAMS OF EARTHED VERTICAL AERIALS.

FIG. Nº 20.



3 - DIMENSIONAL RADIATION DIAGRAM
λ/2 DIPOLE IN FREE SPACE.

FIG. NO. 21.



ℓ = 0.10 λ
ℓ = 0.15 λ
ℓ = 0.20 λ
ℓ = 0.25 λ
ℓ = 0.30 λ
ℓ = 0.40 λ
ℓ = 0.50 λ
ℓ = 0.60 λ
ℓ = 0.70 λ
ℓ = 0.75 λ
ℓ = 0.80 λ
ℓ = 0.90 λ
ℓ = 1.00 λ
ℓ = 1.50 λ
ℓ = 2.00 λ
ℓ = 2.50 λ

VERTICAL POLAR DIAGRAMS OF HORIZONTAL DIPOLES.

FIG. NO. 22.

(ii) It was seen in paragraph 3, Fig. 16 that a reflector can be used to direct the radiation from a single aerial. This principle can also be applied to the arrays mentioned above, and although radiation in a backward direction is never entirely suppressed it is so to the extent of 80 or 90%. Fig. 27 shows the experimentally determined horizontal polar diagram of a helf wave dipole and reflector, erected half a wavelength above earth on guyed steel masts. The distortion is due to the long guy wires, supporting the masts, not being broken up with insulators.

(iii) As with horizontal aerials it is possible to make tiered arrangements of vertical dipoles, as shown in Fig. 26(d) which is the vertical version of 26(c). In the Franklin aerial, Fig. 26(e), radiation from those half wavelengths, which in a straight wire radiator would be out of phase, is avoided by bending the wire into loops as shown, causing the current in the centre part of each half wave loop to flow in the same direction. Thus, each half wave contributes radiation in phase with its neighbours, and produces a beam at increasingly lower propagation angles as the number of loops is raised. As with horizontal aerials these elements can also be arranged side by side to achieve a narrowing of the beam in the horizontal plane. Reflectors can also be added to make the array uni-directional.

Frequency Tolerance of Tuned Arrays.

7. (i) A general characteristic of all aerials and arrays on which standing waves are built up on the radiating elements, is that the frequency can only be varied over very small limits before the mismatch, caused by the elements being forced to operate off tune, becomes so serious that the transmitter is unable to develop full power, as previously mentioned in paragraph 4 (ii). Fig. 28 shows the standing wave ratios produced on open wire feeder lines as the frequency was varied from the matched condition on a one-bay, two-tier array with reflector, erected for 7.56 m.c/s. with single wire elements. The frequency tolerance over which this type of aerial will work, may be broadened to some extent by using large diameter cage elements in place of the single wires as discussed later in paragraph (ii) of Chapter 5. In general, for transmitters designed for matched lines, a 2 : 1 ratio is the highest value which can be tolerated by the transmitter without a serious falling off of power output, though even with this ratio the coupling and final circuit tuning adjustments will be seriously upset and may become unstable, but where it is essential to use an aerial on a different frequency, some relief from standing waves and instability can be obtained by re-matching the aerial.

(ii) A further consideration is that, since the reflecting properties of a parasitic reflector depend upon its tuning and the distance it is from the driven element (paragraph 3.) in terms of wavelengths, it will be seen that if the frequency of the current fed to an array is altered, the initial conditions under which the reflectors were operating satisfactorily will no longer hold, and it is unlikely that they will function at all. Also for a tiered aerial, since the electrical distance between the elements will no longer be the same, the various elements will not be in phase, and consequently, the vertical propagation angle will probably bear no close relationship to the angle at which the array propagates when operating on its designed frequency. These limitations of arrays with tuned elements are a serious handicap where the exact working frequency cannot be specified, or where it may be necessary to move from the original frequency owing to interference or some other cause. The only way in which these disadvantages can be overcome is to use an aperiodic aerial.

The Horizontal Rhombic Antenna.

8. (i) This aerial, which is a diamond of wire horizontally suspended above the ground, has the great advantage of being substantially aperiodic when terminated correctly, and can be operated over a 2 : 1 frequency band without difficulty. It works by virtue of the fact that a long wire in

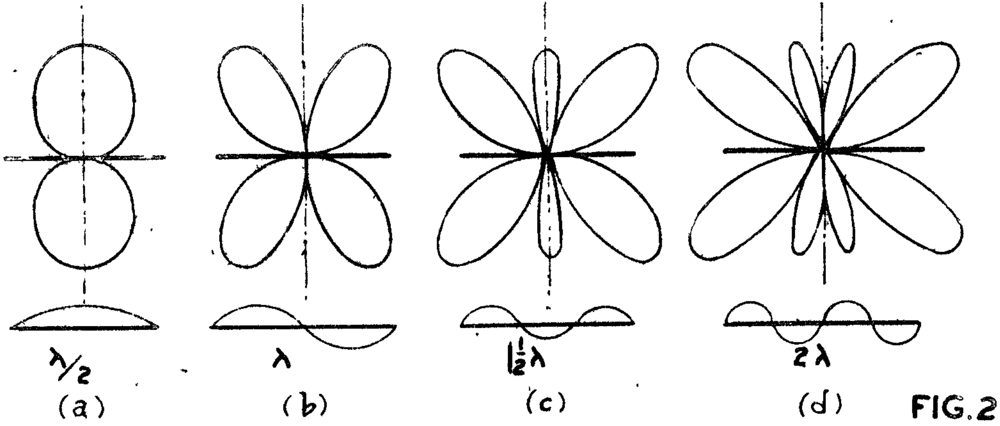
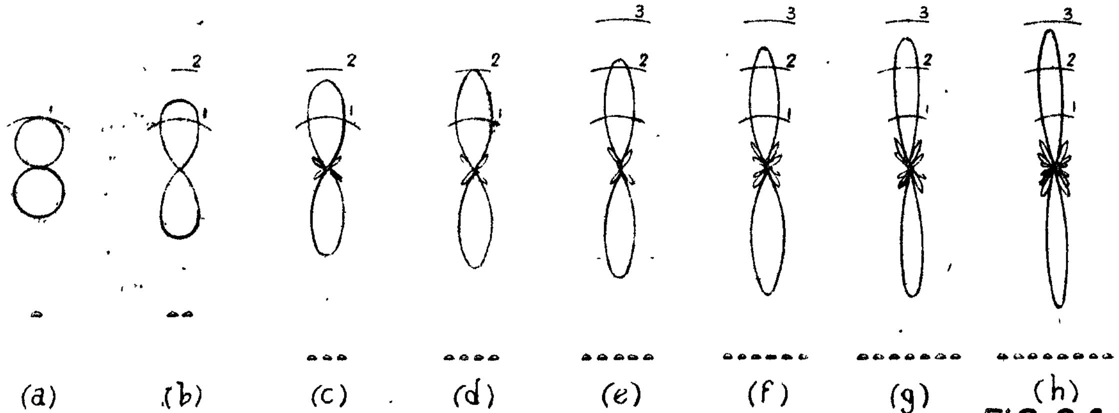
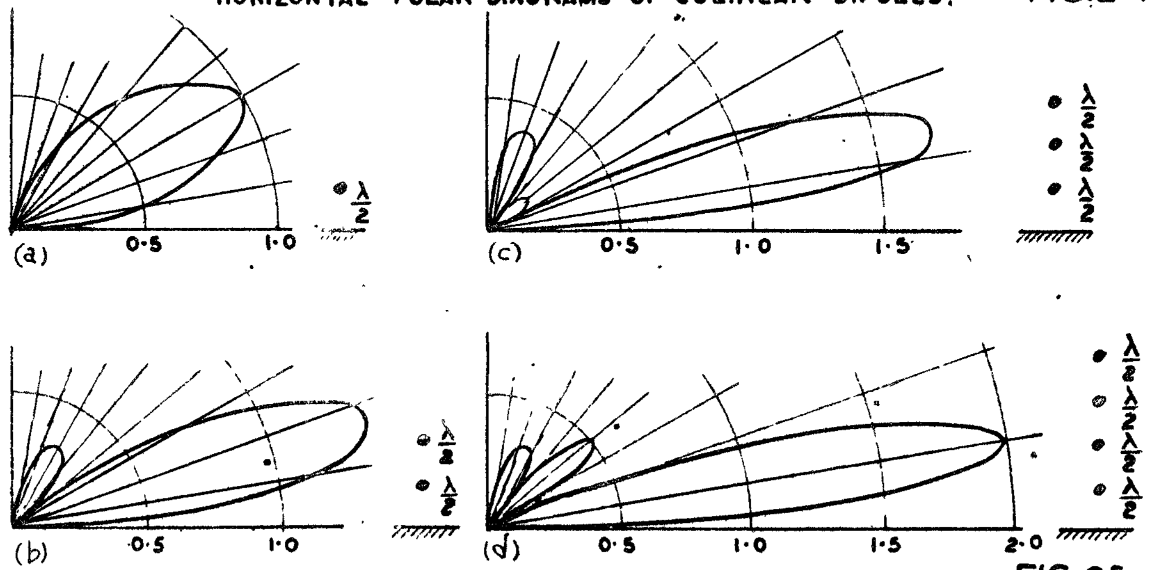


FIG.23.



HORIZONTAL POLAR DIAGRAMS OF COLINEAR DIPOLES. FIG.24.



VERTICAL POLAR DIAGRAMS OF STACKED DIPOLES FIG.25.

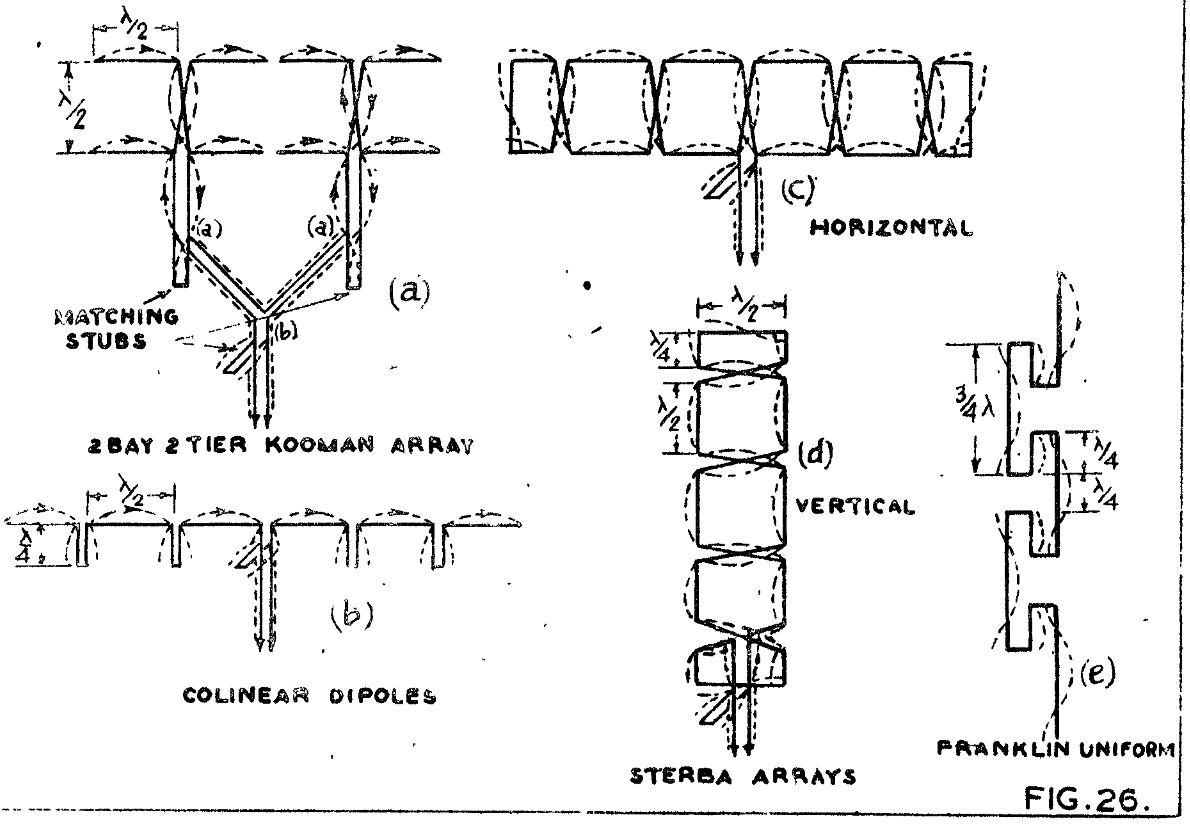
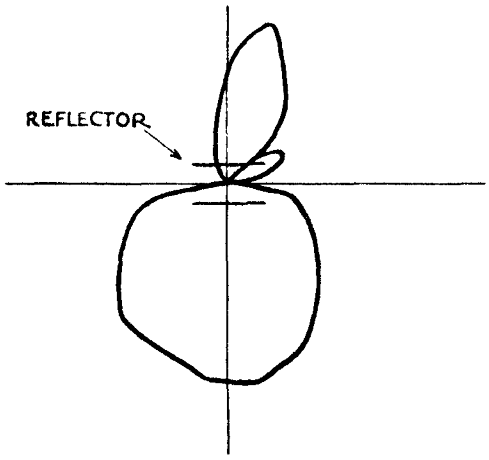
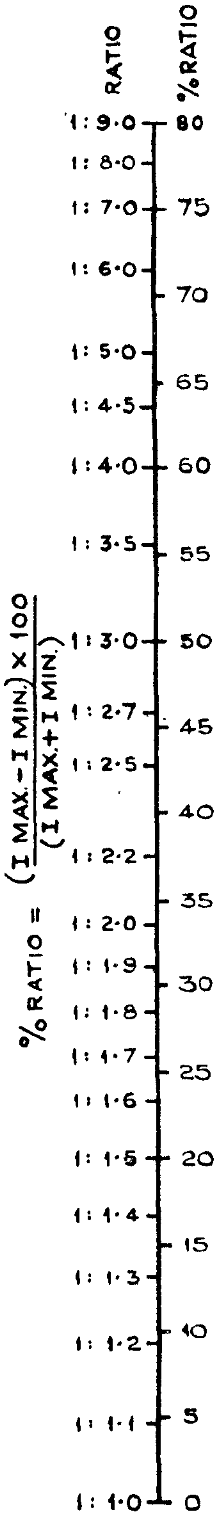


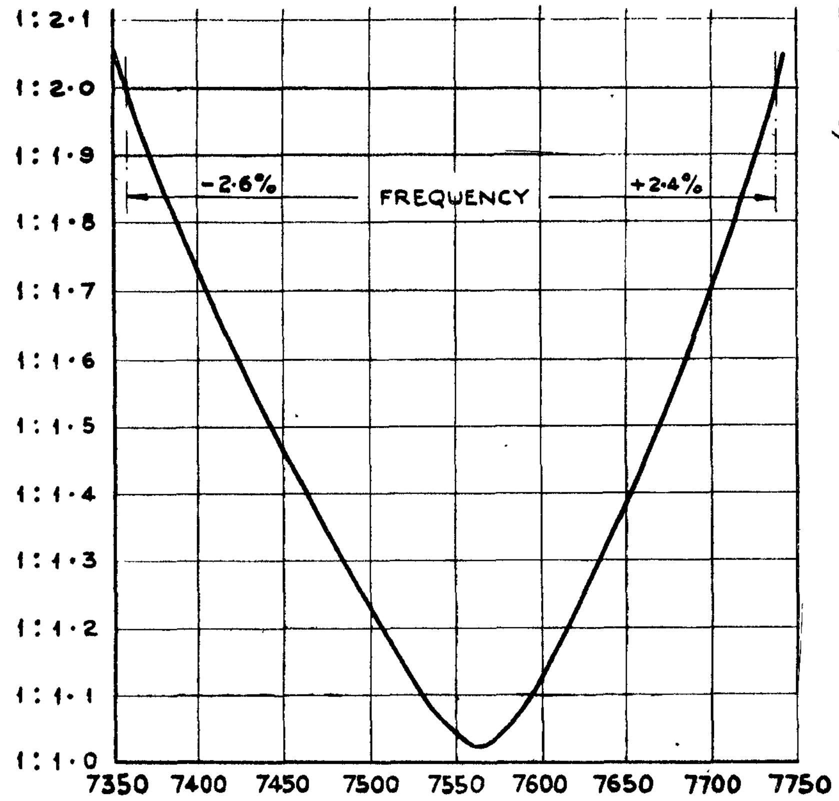
FIG.26.



EXPERIMENTALLY DETERMINED POLAR DIAGRAM AT 10° ABOVE HORIZONTAL OF $\lambda/2$ DIPOLE WITH REFLECTOR ERECTED $\lambda/2$ ABOVE GROUND

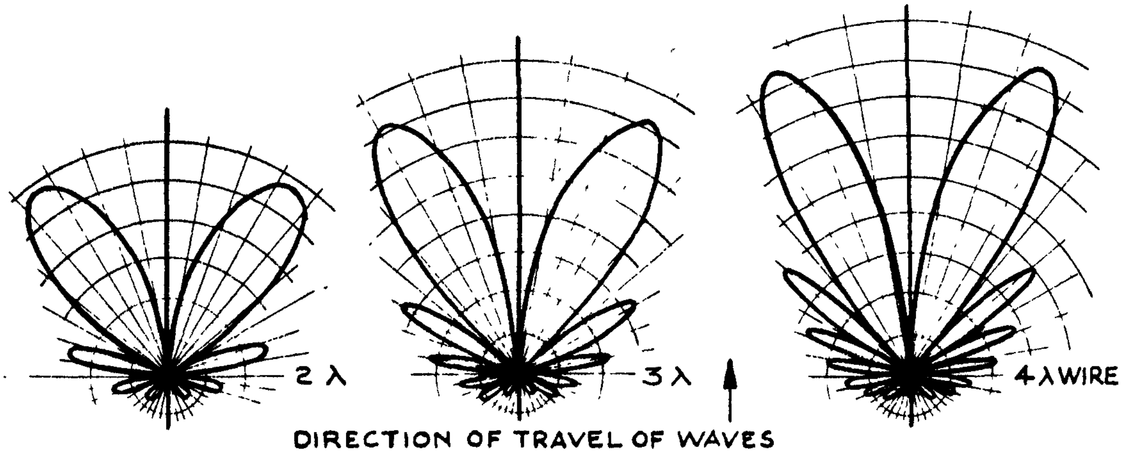
FIG. No. 27





VARIATION OF STANDING WAVE RATIO WITH FREQUENCY FOR A 1 BAY 2 TIER KOOMAN ARRAY WITH REFLECTOR CUT AND MATCHED FOR 7560 KCS.

FIG. No. 28



DIRECTION OF TRAVEL OF WAVES

HORIZONTAL POLAR DIAGRAMS OF A STRAIGHT WIRE CARRYING A TRAVELLING WAVE

FIG. No. 29

free space carrying a travelling wave produces a cone of radiation around it. The angle between the main directions of radiation and the wire becomes progressively less as the wire length is increased, and this is indicated in Fig. 29 which shows the angle between the wire and the direction and relative strengths of the lobes of maximum radiation for various lengths of wire. Thus, a single wire erected over the ground will have a horizontal radiation diagram as shown in the above figure, but in the vertical plane the angle of the lobe will be altered by reflection from the ground, the actual alteration depending on the height of the wire.

(ii) By suitably arranging the angles of the Rhombic for a side of a given number of wavelengths, it is possible to align the lobes of radiation of the wires comprising the sides, to produce one large lobe in the forward direction with greatly suppressed radiation elsewhere. Fig. 30 shows the lobes of radiation of each side wire and the alignment of appropriate lobes.

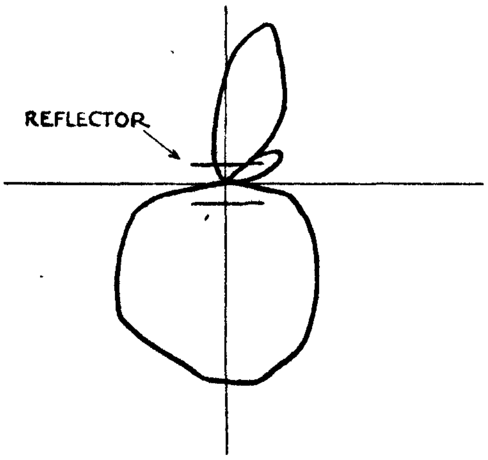
(iii) This suppression of radiation, except in the forward direction, is true, however, if the travelling waves proceed in the forward direction only, and this condition is fulfilled when any unradiated energy remaining at the front end of the Rhombic, is absorbed so that no reflection, i.e. the production of a travelling wave in the opposite direction, occurs. Where such reflection exists the aerial is bi-directional. In this condition the aerial is not aperiodic, and as with tuned aerials the frequency tolerance is very small.

(iv) In order to obtain suitable alignment of radiation in the vertical plane for low propagation angles, the length of each side must be very great, and in the case of aerials required to propagate between 15 - 10° the side length may be as great as 10 - 15 wavelengths, depending on height. This means that a Rhombic erected for a low optimum frequency would have actual lengths of sides so great that they could not be erected in single spans. It is therefore necessary to compromise on length, by choosing a side of a more convenient figure, say 5 wavelengths, at the highest frequency on which the aerial is required to work, and by broadening the Rhombic to re-align the lobes of radiation. As mentioned above, reflection from the ground plays an important part in determining the propagation angle, and thus a compromise has to be made between the conflicting requirements of length for optimum alignment and permissable length, taking into account the effect of height above ground.

(v) The two sets of curves of Figs. 31 & 32 are based on compromise designs and from them suitable side lengths, heights and side angles can be determined for any propagation angle required. In Fig. 31 three curves are drawn for sides of 2, 3 and 4 wavelengths and a further curve gives values for the height of the aerial. For example:-

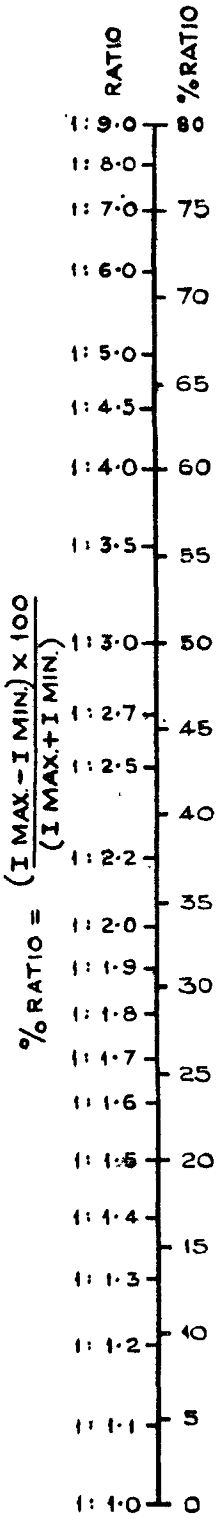
> Given side length L = 3 wavelengths and the desired propagation angle is 18°, to find the height H and the side angle ∅.
> <u>Method</u>:-
> Draw a vertical line from point A (propagation angle = 18°) through point B (on the curve L = 3 w.l.'s). Read half side angle ∅ for point B from right hand scale and height H, from intersection of the line AB at point C on curve H, from left hand scale.
>
> Result:- ∅ = 67° H = 0.82 wavelength.

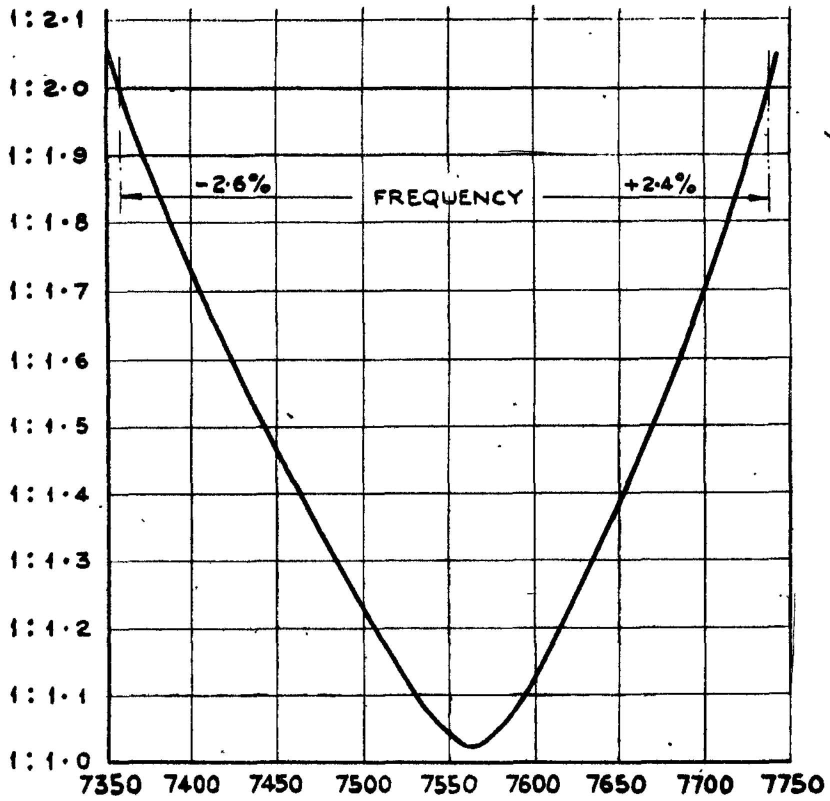
(vi) In Fig. 32 the height has been fixed at .5 wavelength and this determines the relationship between side length and side angle ∅ for a given propagation angle. For example:-



EXPERIMENTALLY DETERMINED POLAR DIAGRAM AT 10° ABOVE HORIZONTAL OF $\lambda/2$ DIPOLE WITH REFLECTOR ERECTED $\lambda/2$ ABOVE GROUND

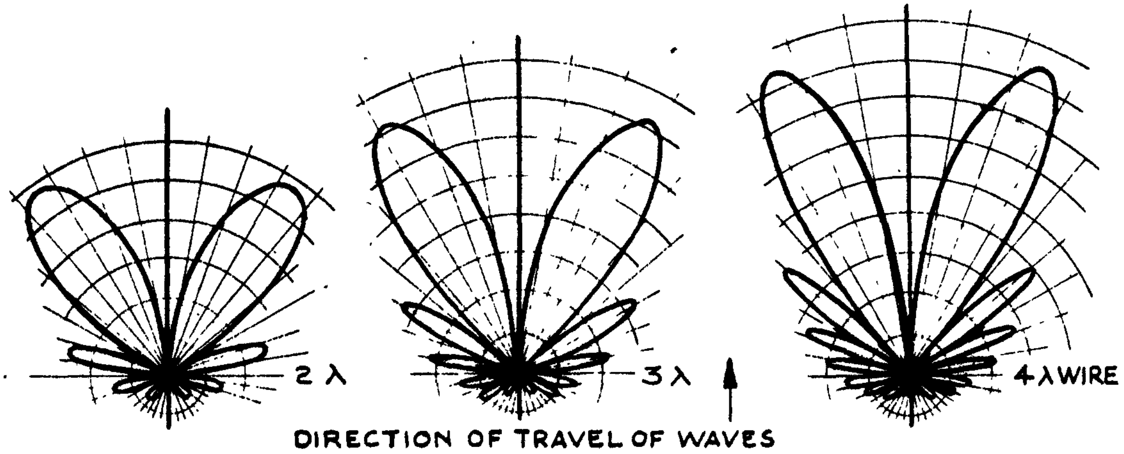
FIG. No. 27





VARIATION OF STANDING WAVE RATIO WITH FREQUENCY FOR A 1 BAY 2 TIER KOOMAN ARRAY WITH REFLECTOR CUT AND MATCHED FOR 7560 KCS.

FIG. No. 28



HORIZONTAL POLAR DIAGRAMS OF A STRAIGHT WIRE CARRYING A TRAVELLING WAVE

FIG. No. 29

Given required propagation angle = 24°. To find side length and side angle.
Method:-
Draw a vertical line from point A (propagation angle = 24°) through curves L and Ø. Read off side length for point of intersection B from left hand scale, and angle Ø for point of intersection C from right hand scale.

Results:- L = 2.6 wavelengths. Ø = 65.9°

Polar Diagrams

9. (i) As mentioned in paragraph 8 the Rhombic aerial is aperiodic and so can be used over a wide band of frequencies. When used this way, however, the side lengths and height in terms of wavelengths will decrease with decreasing frequency, but as the side angles for a given Rhombic are fixed the lobes will not be correctly aligned, except at one frequency; at lower frequencies the polar diagrams in both horizontal and vertical planes will become much broader, and at high frequencies much sharper. Thus, the gain of the aerial will be reduced at lower frequencies and increased at high frequencies, and average values for a Rhombic having a side four wavelengths long at the highest frequency are 9 and 15 db. over a 2 : 1 ratio. In the vertical plane since the height of the aerial in wavelengths has decreased for lower frequencies, and increased for higher frequencies, the angle of propagation will be raised and lowered respectively. Fig. 33 shows the variation over a 2 : 1 frequency ratio of the vertical and horizontal polar diagrams of a single Rhombic.

Impedance Variations

10. (i) Since the wires of a Rhombic carry travelling waves they become in effect a special type of transmission line, so arranged that it radiates. As will be discussed in Chapter 4 one of the fundamental requirements of a transmission line is that the ratio of spacing to wire diameter, and thus the distribution of the inductance and the capacity, is constant throughout its length. The wires of the Rhombic obviously do not remain at a constant ratio, with the result that the impedance at the unterminated end varies from about 900 ohms at low frequencies (sides 2 wavelengths), to about 600 ohms at high frequencies (sides 4 or 5 wavelengths). This effect can be reduced by making the sides of the Rhombic of wire of increasing diameter so that the ratio (for 600 ohm lines 75 : 1) remains constant as the sides diverge. Since, however, the conductor cannot be solid, it is made of single wires arranged one above the other, and this makes it necessary to separate the wires more rapidly; the optimum rate varies with each Rhombic and can only be found by tedious measurements on site, as local conditions affect it, but in general terms a ratio of 1 : 30 for two wires and 1 : 40 for three or four wires will prove satisfactory. The actual improvement effected is such that the impedance of a three-wire Rhombic remains within the limits of 550 - 650 ohms, and consequently, when used for transmitting, can be fed direct from 600 ohm lines without any matching difficulty.

Terminations for Rhombics.

11. (i) Receiving Aerials. Because the power collected by a receiving Rhombic is very small, the terminating resistance is usually made from small carbon resistances joined in series to reduce their capacity, and having a total value of 600 - 800 ohms. The resistances are usually mounted in a watertight paxolin tube, or preferably in three units with a third of the total resistance in each, separated by two or three feet. The unit or units are suspended from the insulators at the front end of the Rhombic.

(ii) Transmitting Aerials. The terminating resistance for transmitting aerials is usually called upon to dissipate between 30

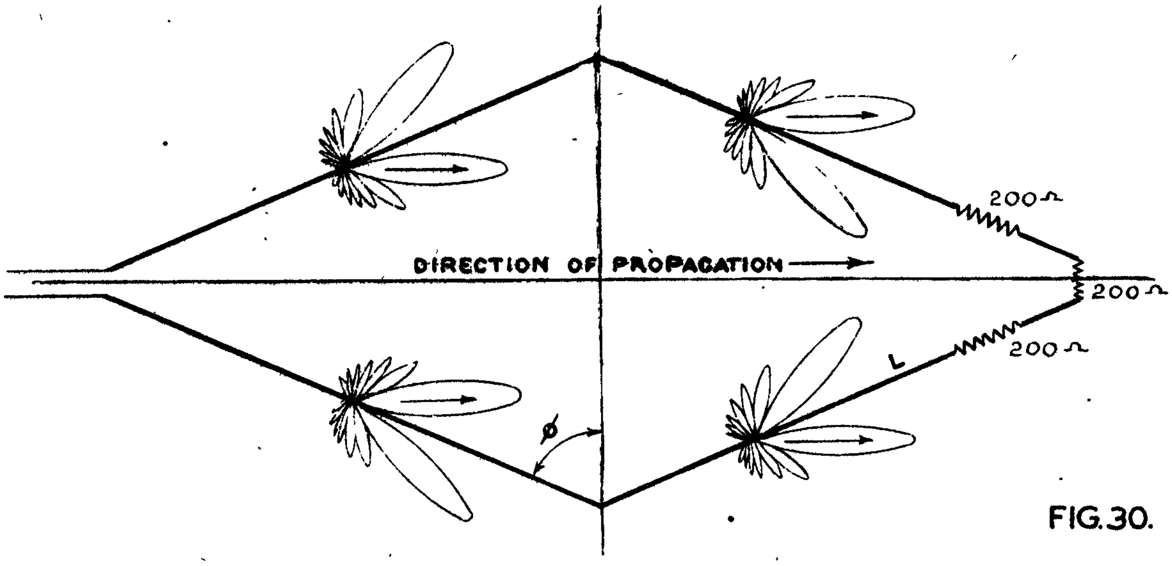


FIG.30.

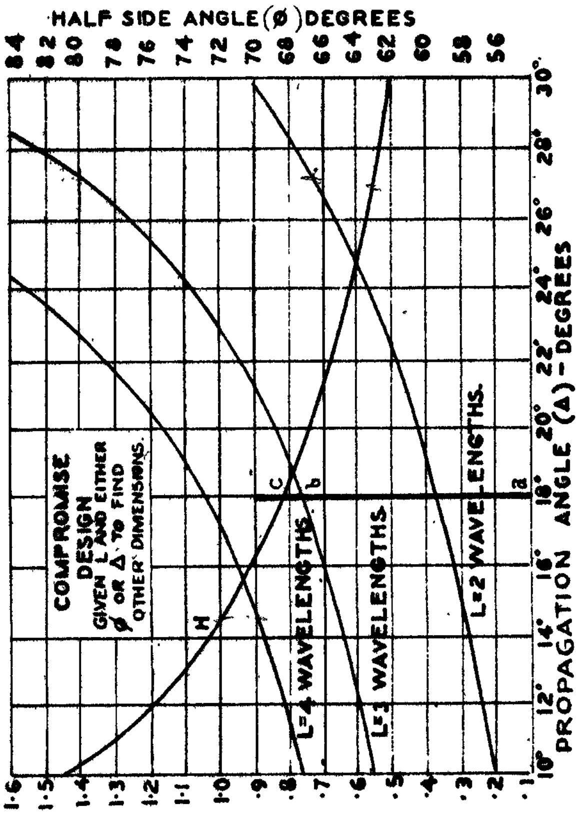


FIG 31.

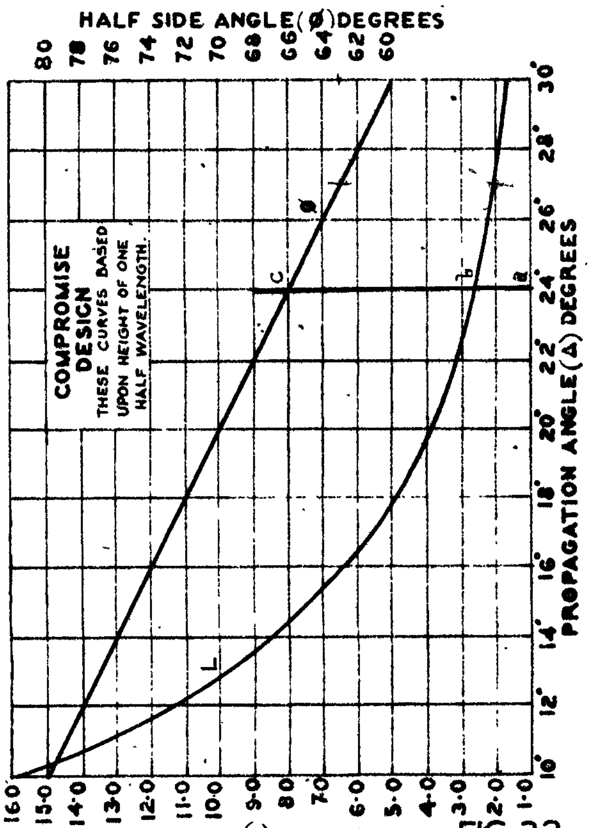
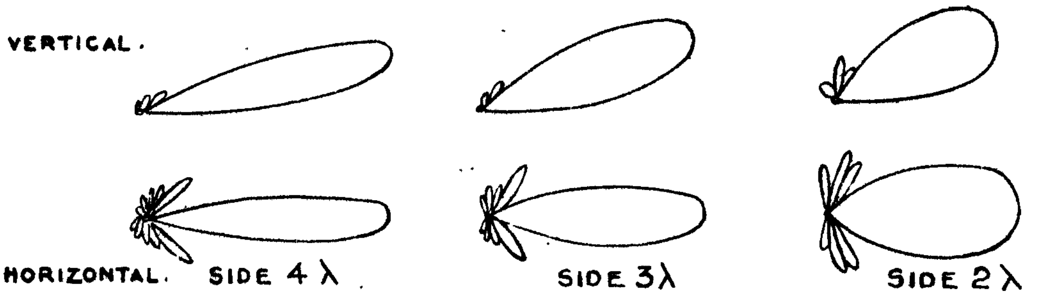
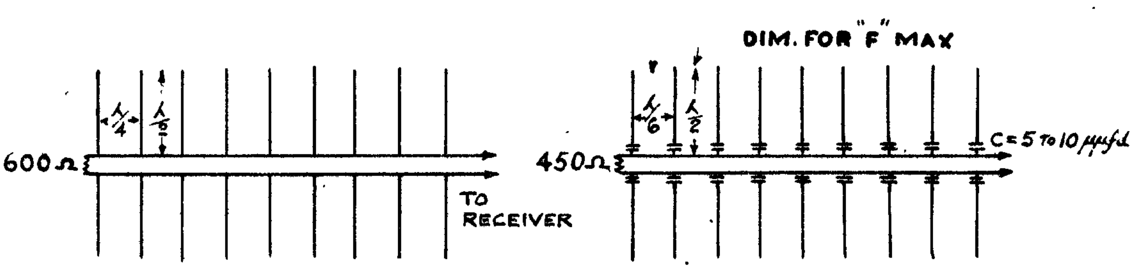


FIG.32.



POLAR DIAGRAMS OF RHOMBIC OVER FREQUENCY RANGE OF 2 : 1

FIG.33.



(a) FREQUENCY RANGE ± 5% ON OPTIMUM

(b) FREQUENCY RANGE FROM "F" MAX. TO 1/3 "F" MAX.

PLAN VIEWS OF FISHBONE AERIALS
HEIGHT 70 TO 80 FT.

FIG.34.

and 60% of the power input to the aerial, consequently in the case of large transmitters, it may be required to dissipate several kilowatts and for this reason must be fairly large. It can be made either as a concentrated resistance comprising high rating carbon resistances suitably mounted close to the front of the aerial and connected to the aerial by open wire lines, or an open wire line may be used as the termination if resistance wire is used for the line and the line made sufficiently long for all the power to be dissipated. A terminating resistance line of this nature can be made from 14 guage Nichrome wires spaced 6" between wire centres, and for frequencies above 10 m.c/s a line 300' long will dissipate all the energy. For lower frequencies the rate of dissipation of energy along the line is less and consequently longer lines will be required. A line 800' long will be satisfactory down to 5 m.c/s or a little lower.

The Fishbone Aerial.

12. (i) Another aerial which has a broad frequency response characteristic is the Fishbone. It consists of a transmission line with half wavelength elements attached at short intervals on either side, and connected either directly or through a small capacity to the transmission line. The aerial operates by virtue of the fact that a travelling wave passing over this array of dipoles along the direction of the transmission line excites them into oscillation, their relative phase being governed by the wave. Thus, a small amount of energy is fed from each dipole element into the transmission line, and provided the line is correctly terminated at the end farthest from the distant station, all the energy extracted from the wave and passed into the transmission line will be absorbed in the termination, i.e. the receiving circuit.

(ii) When the half wave dipoles are connected directly to the transmission line, the frequency tolerance is fairly small as the elements soon impress their off resonance reactance on the transmission line, with the result that the line constants are upset thus preventing a smooth flow of energy along the line. With this arrangement the actual frequency tolerance obtainable is of the order of ± 5% with a gain of approximately 15 db at the optimum frequency.

(iii) When the dipoles are not connected directly to the transmission line their reactance has a much smaller effect on the wave train down the transmission line, with the result that the frequency tolerance is very much greater, extending to as much as a 3 : 1 ratio between the highest and lowest frequencies. As would be expected the gain varies somewhat over this range but has a value of about 10 - 15 dbs.

(iv) For uni-directional reception, the end of the transmission line remote from the receiver must be correctly terminated, in order to absorb any energy produced by waves travelling in the opposite direction. If this is not done then reflection will occur from the unterminated end of the line, and waves travelling back towards the receiver will be set up, thus passing some energy into the receiver. The terminating resistance should have the same value as the characteristic impedance of the line, and this is usually made 600 ohms for the first type with the elements connected directly, or about 450 ohms for the second type. When terminated the absorption of the unwanted energy is fairly complete and the back to front ratio of the aerial is about 20 db. This aerial has an advantage over the Rhombic in that it requires less ground area, but it is more complex to rig. The general arrangement of this aerial is shown diagramatically in Fig. 34.

CHAPTER 3

Choice of Aerials for Various Services.

1. (i) The type of aerial to be used depends upon the Services and distances to be covered and these can be divided most conveniently into the following four groups.

(a) Short distance point to point.
(b) Long distance point to point.
(c) Short distance aircraft control.
(d) Long distance aircraft control.

Short Distance Point to Point.

2. (i) For distances up to 500 miles the primary consideration is the choice of frequency, and the most suitable frequency can be determined by referring to Fig. 12. It will be found to be fairly low and because of this only simple aerials can be erected. The exact type of aerial to be used depends on the distance, and whether communication will be carried out by the ground or reflected ray.

(ii) Ground ray communication can be maintained at these low frequencies up to about 100 miles and for these distances the signal can be strengthened by using a suitable vertical aerial. Reference to Fig. 20 shows that a grounded aerial .56 wavelength long provides the strongest ground wave which can be obtained without introducing fading, caused by radiation at high angles. If radiation is required in specified directions only, then it may be possible to use a reflector to strengthen the field in these directions, and reference to Fig. 16 shows the polar diagrams possible with various reflector spacings.

(iii) For distances over 100 miles and up to 500 miles the indirect or reflected wave will be used, necessitating an aerial producing high angle radiation, and this angle may be found from the curves of Fig. 11. For omni-directional radiation a vertical aerial must be used and from Fig. 20 an aerial of suitable characteristics can be chosen. An aerial three quarters or one wavelength high produces useful high angle radiation, but available mast height will normally limit the aerial to between one sixth and one quarter wavelength.

(iv) A horizontal dipole can be used if the horizontal figure of eight polar diagram is of no disadvantage, and Fig. 22 gives the vertical radiation patterns at various heights. If uni-directional propagation is desired a reflector may be used to increase the signal strength in the desired direction.

Long Distance Point to Point.

3. (i) For distances over 500 miles the choice of frequencies is again of primary importance, and suitable frequencies can be obtained from the curves of Fig. 12, bearing in mind that for distances greater than 1200 miles a number of hops must be assumed.

(ii) As these services normally work in specific directions only, it is possible to erect complex aerial arrays to concentrate the radiated power in the required directions, these may be Sterba arrays, Kooman's arrays, Rhombics etc. Chapter 2 described various theoretical and technical details of these arrays, whilst practical considerations are discussed in Chapter 5.

(iii) It cannot be too strongly emphasised that recent investigations have disclosed that the path of least attenuation, i.e. that over which effective communication is maintained, is entirely dependent on the ionosphere. This means that as the optimum angle of projection from the transmitting station is controlled by the ionosphere, it is relatively indefinite. Thus, a transmitting aerial which radiates over a reasonably broad arc in the vertical plane should be used, and in general terms the angle between 5° and 15° from the horizontal should be well covered. This coverage will not be possible, of course, on very low frequencies without very high horizontal aerials, so that arrays of vertical aerials of the half wave type probably provide the solution; though it should be borne in mind, as mentioned in Chapter 1 paragraph 4 and shown graphically in Figs. 5, 6, & 7, that vertically polarised radiation is much more susceptible to ground constants than horizontally polarised radiation; so that the transmitting site should be chosen with regard to good ground conductivity. In areas where ground conductivity is very poor, i.e. areas of shingle, sand, hard rock, etc., an elaborate earth system must be provided.

Aircraft Control - Short Ranges.

4. (i) For efficient working at short range i.e. R/T, the frequency must be of the order of 3 m.c/s. This is because radiation at very low angles is rapidly lost above this frequency, the polar diagram developing into those shown dotted in Fig. 20. A .56 wavelength vertical aerial will provide the strongest signal free from fading, but as at 3 m.c/s an aerial of this type is 190' high, mast height limitations necessitate using either a 1/4 wave or an inverted 1/4 wave aerial, the 1/4 wave being the easiest to use as it can be fed direct from low impedance coaxial cable (see Chapter 5 paragraph 13 for details.)

Aircraft Control - Long Range.

5. (i) As communication is now dependent on reflection from the ionosphere, optimum frequencies should be chosen from the curves of Fig. 12, and as the entire range from base to 1200 miles must be covered there must be no skip areas i.e. the field strength/distance curve should be that of Fig. 4b. This means that at distances of 75 - 200 miles fading will be severe but this limitation has to be accepted.

(ii) The fading may be minimised by using an aerial radiating a very small amount at very high angles, or alternatively using a frequency so near the critical frequency that this high angle radiation penetrates the layer and is lost, but as this latter method depends on the ionosphere, it is not of much practical use as the frequency cannot be changed often enough to keep pace with the rapidly changing layer conditions.

(iii) Referring again to Fig. 20 the 1/4 wave vertical probably provides the best general purpose aerial, though for consistent working at limiting ranges the .56 aerial will give the strongest signal. Provided the figure of eight horizontal polar diagram is no disadvantage a horizontal dipole erected .4 - .45 wavelength above earth (see Fig. 22) will also give good results.

CHAPTER 4.

Transmission Lines.

1. (i) Since transmitting aerials are often large and complex, and a single communication channel usually requires two or three aerials, working on different frequencies for different times of day, they must of necessity be erected some distance from the building housing the transmitter. Thus, it is necessary to use some low loss non-radiating link between the transmitter and the aerial. This link or transmission line can be of the "open wire" type, consisting of parallel wires about 10' above the ground spaced a very small fraction of a wavelength apart, and mounted on insulators at 70 - 100' intervals, or can be a coaxial line in which one conductor is surrounded by the other conductor, the spacing between the two being maintained by insulating washers at frequent intervals. As commonly used, however, the central conductor is a flexible wire and the outer, also flexible, is supported on low loss insulating material.

Characteristic Impedance of Open Wire Lines.

2. (i) If an alternating voltage were applied across an infinite length of transmission line a current would flow, and the ratio of voltage/current (E/I) is called the characteristic impedance of the line. The value of this impedance Z_o is determined by the square root of the ratio of Inductance/Capacity ($\sqrt{L/C}$) per unit length.

(iii) For open wire lines or feeders, where the dielectric or insulating medium is nearly all air, the characteristic impedance Z_o can be fairly easily calculated depends only on the size and spacing of the conductors, and $Z_o = 276 \log_{10} 2S/d$, where "S" is the centre to centre spacing and "d" is the diameter of the conductors. This formula is only accurate if the ratio of 2S/d is fairly large, for smaller spacings the mathematics are very complex and Table II gives the characteristic impedance of close spaced 1/4" and 1/2" diameter tubes.

TABLE II

Spacing S in inches	Z_o ohms for 1/2" diam. Tubes.	Z_o ohms for 1/4" diam. Tubes.
1.0	170	250
1.25	185	277
1.5	210	198
1.75	225	318
2.0	248	335

(iii) Fig. 35 shows the characteristic impedance of open wire lines for various ratios of 2S/d, and Fig. 36 the characteristic impedance for various pairs of wires with different spacings and wire gauges.

Characteristic Impedance of Coaxial Feeders.

3. (i) Since one conductor of a coaxial feeder is entirely surrounded by the other, as would be expected the capacity between the two per unit length is greatly increased, and the inductance similarly reduced. Thus, coaxial cables are characterised by having a low impedance, and provided the dielectric is mainly air this is given by $Z_o = 138 \log_{10} D/d$, where "D" is the inside diameter of the outer conductor, and "d" is the outside diameter of the inner conductor.

(ii) In most cases, however, and especially in the flexible types of cable now used very widely, the dielectric is far from being all air, and as its composition varies very greatly the formula above will be of little use, and it is necessary to rely on the figures provided by the manufacturers. At Appendix "A" is a list giving the characteristic impedance, attenuation, and other details of various types of coaxial cable.

Losses in Transmission Lines.

4. (i) As the conductors in a transmission line are not perfect, some of the energy passing down the line will be lost in heat through their resistance; this loss is proportional to the square of the current flowing (I^2R), while R varies directly with the circumference of the wires or tubes. Thus, for equal I^2R losses the conductors of the coaxial line must be much larger than those of an open wire line. As well as this resistance loss there is a dielectric loss in the insulators, and this is approximately proportional to the square of the voltage. Thus, the loss per insulator on open wire lines, with their higher impedance and consequently higher voltage for a given power, will be greater than the loss per insulator on coaxial lines, but coaxial lines require many more insulators. The net result of these factors is that in well constructed transmission lines of either type the attenuation is much the same, but the cost of the coaxial will be about five times that of the open wire line. An average figure for the loss of an open wire line (300 lb per mile copper) is 3 dbs per mile at 10 mc/sec.

(ii) A further source of loss is that of radiation from the line, though naturally this can only apply to open wire feeders. It has been shown that the radiation from an open wire line, well above earth and carefully balanced to it, is equivalent to that from a single wire radiator carrying twice the current of the feeders, and of the same length as the distance between the wires, this loss being independent of line length. Where the feeders are unbalanced, however, there will be a residual field between one line and earth, and an appreciable amount of energy will be radiated if this unbalance is at all large.

Termination of Feeders.

5. (i) If, as mentioned previously, the feeder is of infinite length then power from the transmitter is gradually attenuated due to ohmic and dielectric losses so that energy is never reflected, but if the line is of relatively short length, and is terminated by a circuit whose electrical characteristics are different from those of an infinite line, then an advancing wave on meeting this termination will be partially or wholly reflected. For example in two extreme cases if the line is open circuited, then obviously having nowhere else to go waves will be reflected straight back. In the other case, if the line is short circuited, then the advancing waves will pass through the short circuit from either side and proceed against oncoming waves in a similar manner. Thus, at any part of the line the actual voltage or current will be the sum of the advancing and returning waves. This gives rise to a stationery pattern of current and voltage on the line, and these stationery waves are known as standing waves. Measurement of current along the line from the terminated end at frequent intervals will show that the standing wave of current varies in a cyclic manner; if the termination is a short circuit then it will be found that there is a current maximum at this point, and a half wavelength away a further current maximum. At the intermediate point the current will be zero or very nearly so, and it will be found that at this point the voltage will be high. Half a wavelength farther on from this voltage point the current, after passing through the current maximum already mentioned, will have again dropped to zero, and examination along the line will show that these conditions repeat at half wave intervals as indicated diagramatically in Figure 37. The ratio between maximum and minimum current readings is known as the standing wave ratio and is expressed as this ratio, a fraction Imin/Imax, or as a percentage.

$$\text{Percentage ratio} = \frac{\text{Imax} - \text{Imin} \times 100}{\text{Imax} + \text{Imin}}$$

(ii) In cases where the line is terminated by either of the extremes mentioned above, the standing wave ratio, assuming the lines have no losses, will be 100%, but as in fact they have the ohmic and

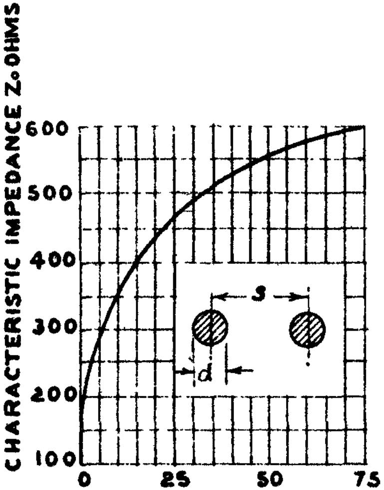


FIG.35.

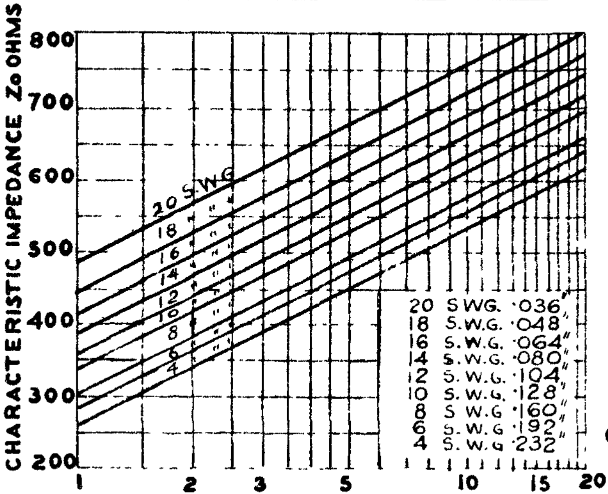
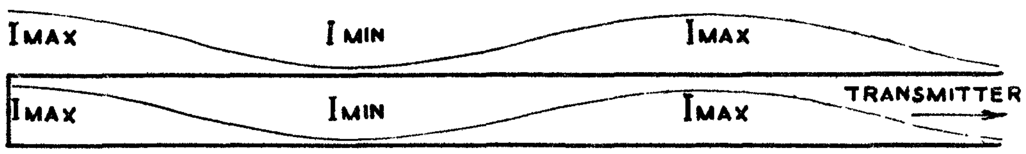
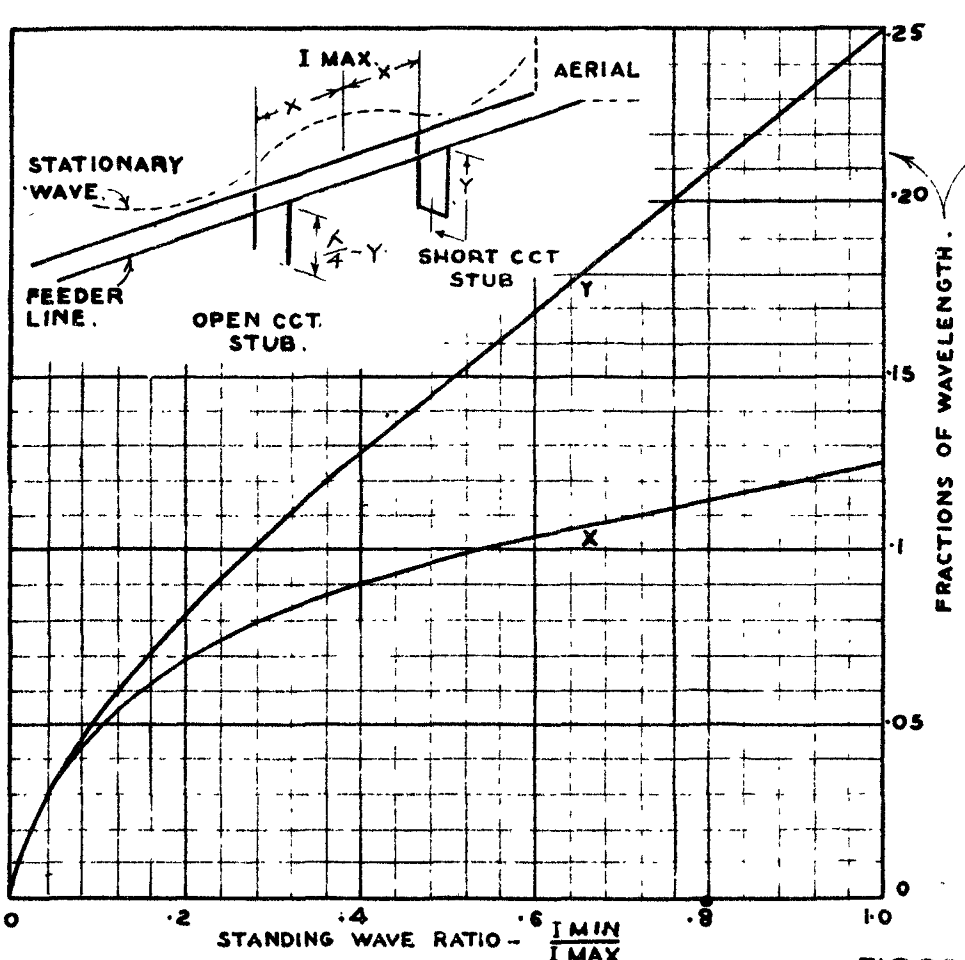


FIG.36.

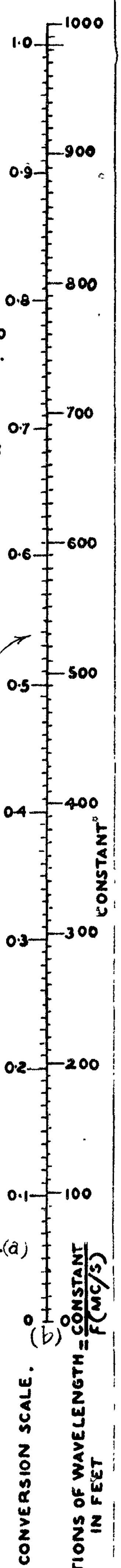


STANDING WAVES ON SHORT CIRCUITED FEEDER.

FIG.37.

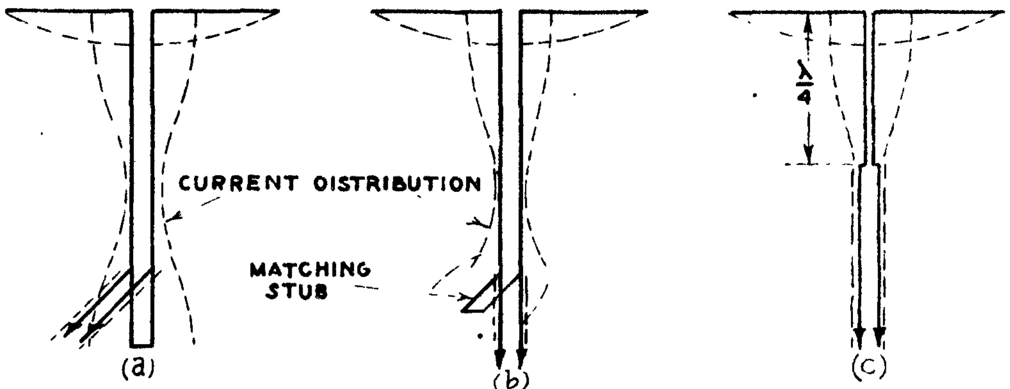


CURVES FOR CALCULATING IMPEDANCE MATCHING STUB. FIG.38.(a)



(b)

CONVERSION SCALE.



METHOD OF FEEDING λ/2 DIPOLES FROM OPEN WIRE TRANSMISSION LINES

FIG.39.

dielectric losses referred to previously this ratio will be a little less. Where the line is correctly terminated, however, the percentage standing wave ratio will be zero as there is no reflected wave, and a meter moved along the line would register only the steady (RMS) value of the advancing current wave. This is the most efficient condition for transference of energy by the line, as there will be no high current points (loss proportional to I^2) and no high voltage points (loss proportional to V^2), and the radiation loss due to any unbalance to earth will be a minimu. Thus, for efficient operation of transmission lines standing waves are to be avoided.

(iii) In conditions where the terminating impedance is neither a short nor an open circuit, but is not of the right value to terminate the line correctly, a certain amount of the energy of the advancing wave will be usefully used, the remainder on being reflected will produce a standing wave ratio of some value between 0 and 100%. Since this reflected wave contributes no energy to the aerial or terminating impedance, it can be regarded as being produced by a reactance in parallel with the resistance which is absorbing energy usefully, but since the effect of any reactance can be cancelled by an equal and opposite reactance it is only necessary to provide such a reactance in order to remove standing waves.

Stub Matching.

6. (i) The reactance required to cancel the standing waves could be either a coil or condenser of suitable value, but is most easily made up as a length of feeder line, either open or closed at the end not attached to the transmission line. The length of this stub line is determined by the standing wave ratio, and its position on the transmission line by this ratio and by the location of the standing wave. For any standing wave ratio there is always the choice of either an open or a closed stub line, and in general the stub which is nearest to the termination should be used. The length and position of the stub line for any standing wave ratio can be determined from the curves of Fig. 38.

(ii) The manner by which these stubs operate may be more easily understood by referring to Fig. 39a, which shows a half wave horizontal dipole broken at the centre by a half wave feeder line terminated in a short circuit. Tracing currents along these lines it will be seen that the current maximum at the centre of the dipole, turns down the feeder lines, and a quarter wavelength down becomes almost zero, reappearing and rising to a maximum but in phase opposition at the bottom of the line. In other words the half wave dipole and the line form a tuned circuit. It will be seen that there is a current maximum at the shorting bar, but that a quarter wavelength up the line the current in either feeder has dropped to a low value. The ratio between the currents at this point, and the current in the shorting bar, will depend on the characteristic impedance of the tuned line. Assuming the tuned line impedance to be 600 ohms and the aerial impedance 70 ohms, then the impedance at the current minimum will be $600^2/70 = 5142$ ohms.

(iii) From the above it follows that if the impedance at the bottom is 70 ohms, and a quarter wavelength up the line is 5142 ohms, then at some intermediate point it will be the correct value to match any twin wire feeder line. Thus, by tapping 600 ohm feeders on to this resonant loop at the correct point (Fig. 39(a)) there will be no standing waves in the feeders, and all the energy will be delivered direct to the tuned loop and hence to the aerial. Fig. 39(b) shows the case where the main 600 ohm feeder lines are continued directly to the half wave aerial, and a suitable shorted matching stub connected to remove the standing waves produced by the mismatch at the aerial. A close examination of this system shows that electrically it is identical with that of Fig. 39(a), but its application is much more straight forward as any unpredictable effects due to the proximity of other aerials, masts, or stay wires are automatically taken into account, whereas a considerable amount of trial and error work may be necessary to find the correct tapping point on the tuned line.

(iv) When using a shorted stub the distance "Y" in Fig. 38 should be measured to the centre of the shorting bar at the bottom of the stub, and this point may be earthed if protection against lightning discharges is required. When using an open stub it should be remembered that the voltage at the open end will be high, and adequate insulation must be provided. Where a greater power than 5 k.w. is being used then the voltage may be high enough to produce corona discharges from the wire ends, and to prevent this, insulators with corona rings must be used. As the capacity of the metal ring is fairly large, the stub length must be shortened to allow for this. 9" and 1' for $3\frac{1}{2}$" and $4\frac{1}{2}$" diameter rings respectively, are approximate amounts to be taken off the length obtained from Fig. 38 for the 12" insulators detailed in Appendix "C"

Quarter Wave Matching Lines.

7. (i) It has been noted that the impedance of a quarter wave section of line varies from a low value at one end to a high value at the other, and that the ratio of these impedances depends on the characteristic impedance of the line. It thus behaves as a transformer and it is possible by using a quarter wave line of the correct characteristic impedance to match between almost any two impedances Z_1 and Z_2. The characteristic impedance Z_0 of the quarter wave line is the correct value when it is the geometric means between Z_1 and Z_2 i.e. $Z_0 = \sqrt{Z_1 Z_2}$. Thus, it would be possible to match the half wave dipole of Fig. 39(a) by a quarter wave line whose impedance $Z_0 = \sqrt{70 \times 600} = 205$ ohms. This arrangement is shown in Fig. 39(c) and a line of suitable impedance can be chosen from Table II, paragraph 2.

(ii) The quarter wave transformer is also useful for matching arrays such as those shown in Fig. 26 (a - d), where the ratio between Z_1 and Z_2 may not be very great. In this case starting from a current maximum as near as possible to the aerial, measure off .24 wavelength (for length in feet see Fig. 38(b)) along a clear section of line, and install spacing insulators to keep the ends apart at their original spacing, then using small insulators between the wires pull the wires together until standing waves are eliminated along the lines to the transmitter. This process can be repeated as often as necessary to match arrays, i.e. Koomans, which are fed at more than one point. The highest standing wave ratio which can be handled by the procedure above is 2 : 1, for beyond this the wires become much too close together for all but low power and good weather conditions.

Measurement of Standing Waves.

8. (i) In the preceding paragraphs, reference has been made to the need for knowing accurately the standing wave ratio on transmission lines in order to calculate suitable stubs. A standing wave meter is necessary for this, and it should be capable of reading over a ratio as great as 10 : 1. Meters are usually made to work by induction from the transmission line, so that there is no need for a running contact. The simplest form consists of a loop of wire of triangular shape with a thermo-milliameter at one corner. The side opposite this corner is usually made about 18" long and is so arranged that it can slide along the transmission line. Where the transmission lines are very high above the ground, a twisted flexible lead can be brought above the ground, a twisted flexible lead can be brought down from the loop to the meter, and the loop mounted on a piece of wood can be moved along by means of a stick or piece of string. For satisfactory operation one thermo-milliameter is not sufficient, as a current range of 3 : 1 is as much as one meter will read accurately. It is thus necessary to provide two meters, one having a range, say 0 - 120 milliamps and the other 0 - 500 milliamps, with a suitable push-button switch to bring in the 0 - 120 meter for low readings. A drawing of a standing wave meter of this type is shown in Appendix "F".

Measurement of Power in Feeder Lines.

9. (i) Since the power flowing along the feeder line is proportional

to I^2Z_0 where Z_0 is the characteristic impedance of the line, then by measuring the current in a line the power can be calculated. This is only true, however, when no standing waves are present, for when present the current will vary along the line, and to obtain the power the values of Imax and Imin must be measured and their product substituted for I^2, i.e. Power = Imax X Imin X Z_0

(ii) The standing wave meter can also be used to indicate power, though unless calibrated relative amounts only are measurable. When used in this way the standing wave meter can be very helpful as the power loss at wall insulators and along transmission lines can be measured, thus enabling steps to be taken to correct the faults at any place where the loss is found to be excessive.

Matching Units.

10. (i) In the previous paragraphs, methods were discussed for terminating transmission lines in such a way that standing waves could be avoided, and it was mentioned that a coil or condenser could be used to tune out any unwanted reactance. There are occasions when this method has advantages over the application of stub or quarter wave matching lines, for as they are critically dependent upon the length of the wires, operation is only satisfactory when working on the frequency for which they were initially adjusted. The frequency range of the quarter wave transformer is thus very limited, but this limitation can be overcome by building an actual transformer from coils and condensers. The turns ratio for correct matching between primary and secondary is given by the square root of the impedance ratio i.e. a 16 : 1 impedance ratio requires a turns ratio of 4 : 1. For a broad frequency coverage with a transformer, the fundamental requirement is that the coupling factor "K" between primary and secondary should be as close to unity as possible. This requirement is very hard to achieve for high power transformers, as the high voltages and currents mean large coils adequately spaced, and this causes a reduction in coupling. For receiving aerials where the power handled is negligible, it is possible to use small and compact coils with iron dust cores. This makes very close coupling possible and a frequency coverage of 2.5 to 20 m.c/s is obtainable from a single unit.

(ii) A unit of this type, such as the Matching Unit type 68 (see Appendix "B") is used to match from a 600 ohm balanced line to a 75 ohm single coaxial cable, i.e. for matching a Rhombic or multiwire receiving aerial into 75 ohm coaxial cable. In the Matching Unit type 2 an auto transformer is used to match the 40 ohm unbalanced load of a quarter wave vertical aerial, into 75 ohm coaxial cable.

Notes on Efficient Operation of Transmission Lines.

11. (i) From the foregoing it will be seen that many points must be borne in mind for the efficient operation of transmission lines and some of them are listed below.

(1) Standing waves must be eliminated, and the process by which this is carried out is known as matching. The curves of Fig. 38 give the information for stub matching.

(2) The size of the conductor should be as large as possible, within reason, to minimise resistance losses.

(3) Insulators should be of good quality and have long leakage paths. Where pin type insulators are used for open wire type feeders, the metal pin should not be closer to the feeder wire than two or three inches. For example, Post Office telegraph insulators with the metal mounting pin close to the feeder wire, are unsatisfactory as they upset the distribution of line capacity, and on high power sufficient heat may be developed in the insulator to melt the locking compound with consequent failure. Surface

leakage losses must be reduced to a minimum by keeping the insulators free from oil, dirt, etc. and by using those types provided with "skirts", e.g. type 19 wherever possible.

(4) The spacing of open wire feeders must be maintained constant throughout their length and the lengths of the wires of a pair must be equal.

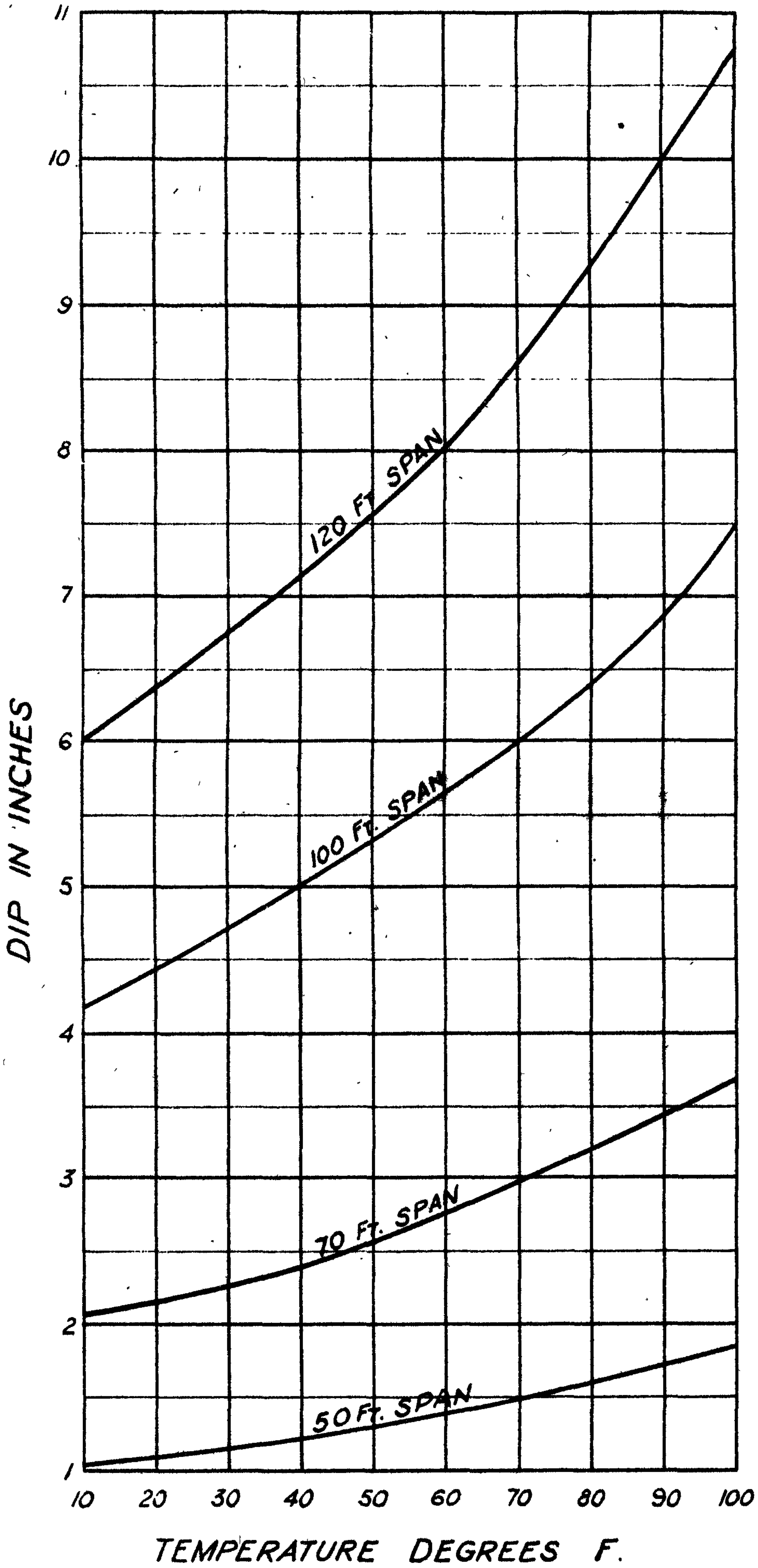
(5) Sharp bends must be avoided wherever possible and where it is necessary to turn corners. It must be done in such a way as to ensure that the individual lengths of feeders remain equal.

(6) Open wire feeders should be maintained reasonably high above ground, and as a general rule not less than six feet.

(7) No metallic objects or wires should be permitted within a distance of about three times the spacing between the wires and all joints must be as small as possible in order to maintain the even distribution of capacity and inductance.

(8) When rigging transmission lines sufficient dip should be allowed in each span to permit the wire to contract in cold weather without breaking. The dip for the temperature at which the lines are being rigged can be chosen from the curves of Fig. 41.

(9) Unless it is known that feeder lines are accurately matched a meter or meters in the feeder wires at the transmitter conveys little or no information as to the power output of the transmitter, and may be grossly misleading.



CURVES GIVING DIP IN TRANSMISSION LINES TO BE ALLOWED FOR VARIOUS SPANS AND TEMPERATURES

FIG. No. 40

CHAPTER 5.

Practical Aspects of Aerials.

1. (i) For the satisfactory operation of any tuned aerial it is essential that the length of the driven element be adjusted so that it is exactly in resonance. This length as a fraction of a wavelength, is not constant with frequency, and for half wave dipoles is about .48 wavelength at frequencies of approximately 3 m.c/s falling to about .45 wavelength at 20 m.c/s. This length is, of course, greatly modified by the insulators and wire used, and also by the nature of supporting masts, stays, halyards etc. Curve (a) of Fig. 41 gives the resonant length for a half wave dipole of 14 guage wire, with 6" glass insulators suspended between wooden towers by rope halyards, and curve (b) gives the resonant length for a half wave dipole but with insulators fitted with Corona rings. Curve (c) gives the resonant length for quarter wave vertical aerials, and is based on the assumption that the aerial is hauled up well clear of any metal work, and that 6" glass insulators are used in conjunction with rope halyards. The length of the aerial, as obtained from the curve must be measured from the ground level, i.e. it must include the height of the stirrup of a radial earth (Fig. 49). The use of steel masts with stay wires unbroken by insulators, is often necessary and may render the curves of Fig. 41 very inaccurate at frequencies for which the stays approach resonance. Similar inaccuracies can also be produced by other aerials in close proximity, and in general the effect will be to shorten the length of wire required for resonance.

Cage Aerials.

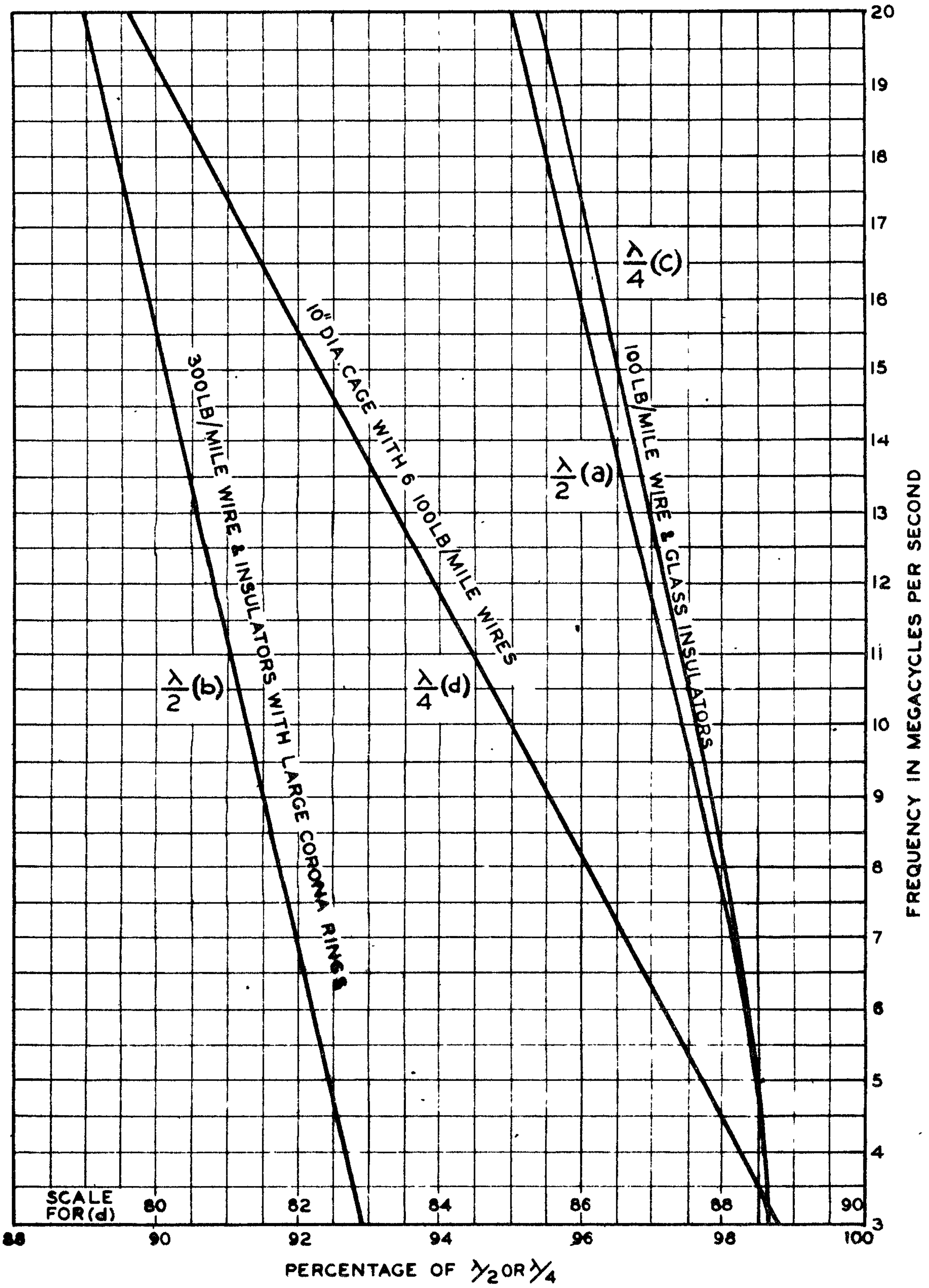
2. (i) In this aerial, by mounting wires around the circumference of circular spreaders, a conductor having a large effective area is produced. Because of this the capacity per unit length is greatly increased, and as the wires are in parallel, the inductance of the cage is much lower than that of a single wire, with the result that the characteristic impedance ($\sqrt{L/C}$ per unit length) is greatly reduced. This similarly reduces the impedance ratio along a quarter wavelength, and broadens the tuning of the aerial, sufficiently for a frequency band of ± 7% on the optimum to be covered for a 2 : 1 standing wave ratio at the limits of the band. The increased capacity, however, has the effect of reducing the overall length of cage required for resonance, and curve (d) Fig. 41 gives the length for quarter wave vertical cages. This method of broadening the frequency response can also be used for horizontal aerials, and is of advantage where Kooman type arrays are being used, the resonant length for the half wave element of this array being twice that of the quarter wave vertical. The system can also be used for half wave dipoles, but it is better when feeding this aerial from open wire lines to adopt the folded wire arrangement described in paragraph 8.

Horizontal Dipoles.

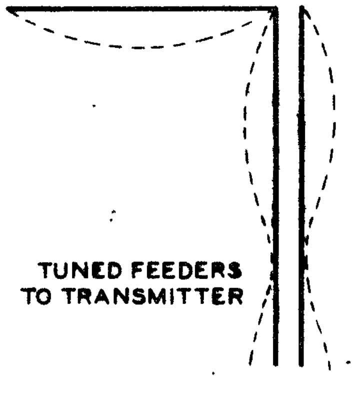
3. (i) The horizontal dipole in various forms is very widely used, and appears with various methods of feeding it under a variety of names, some of which are described below.

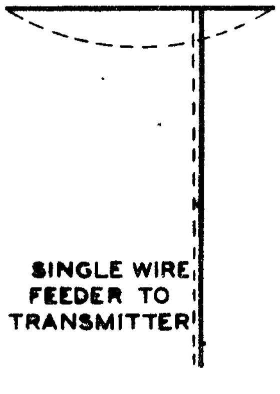
The Zepplin.

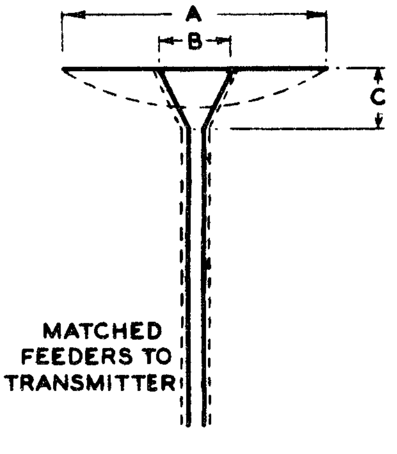
4. (i) Fig. 42 This is a voltage fed dipole with tuned feeders, which owing to the heavy standing waves and the unbalanced load on them, always radiate to some extent; for this reason and because of increased line losses due to the standing wave, the feeders should be as short as possible and are usually made an odd number of quarter waves long, in order to avoid high voltages at the transmitter. This system is popular with amateurs as it can be operated on harmonic frequencies very easily, but for communication work the higher powers used would mean dangerously high voltages and currents on the feeders, and it is not of much use as most transmitters must work into matched and balanced lines.



RESONANT LENGTHS OF AERIALS FIG. No.41







NOTE - DOTTED LINES INDICATE CURRENT DISTRIBUTION

ZEPPELIN
FIG. No.42

WINDOM
FIG. No.43

'Y' MATCHED DIPOLE
FIG. No.44

The Windom.

5. (i) Fig. 43. As the impedance of a wire in resonance is purely resistive at any point, and for a half wave dipole varies from about 73 ohms at the centre to about 2,500 ohms at the ends, it follows that at some point either side of the centre it will be the right value (500 - 700 ohms) to match a single wire feeder, so that the current in the feeder wire will be free of standing waves, and consequently radiation slight compared with that from the "dipole". The exact distance of the feed-point from the centre can only be found by experiment but will be about .06 wavelength. Because radiation from the feeder wire is an inherent fault, and the load on the transmitter is unbalanced, the system is not greatly used, except with low power mobile equipment.

"Y" or Delta Matched Dipole.

6. (i) Fig. 44. If two feed wires are used and tapped on to the dipole, each about .06 wavelength from either side of the centre, then each wire will be correctly terminated and their currents - equal because the load is unbalanced - will be in opposite directions, and no radiation will take place from the feeders. Since .12 wavelength will be longer than the distance between the feeder wires, it will be necessary to fan out the two wires into a "Y" and hence the name of the aerial. The length of the top "A" for various frequencies can be obtained from paragraph 1 and Fig. 41. For 600 ohm feeders the distance "B" between the two tapping points is .125 wavelength or in feet 123/F (M.c/s). The distance "C" is .15 wavelength or in feet 148/F (m.c/s). The height of the aerial above the ground and the proximity of masts, stay wires etc. will cause the precise lengths of A, B and C to vary slightly, and they can only be exactly determined by experiment on site, and the procedure is as follows:-

(1) Measure the standing waves on each feeder wire and if they are unbalanced move the "Y" as a whole along the top to left or right until the currents are balanced.

(2) Alter the distance "B" until standing waves are reduced to a minimum. If they cannot be reduced below 10% distance "A" is probably too long and should be shortened by 2 or 3 inches and variation of "B" tried again. A final value of 5% or less should be attainable, Length C may require shortening a little at high frequencies (15 - 20 m.c/s). All lengths A, B and C are critical to an inch or two (depending on frequency) and so careful attention should be paid to measurements during construction.

Centre Fed Dipoles.

7. (i) Fig. 39 (a - c). A half wave dipole in free space has a centre point radiation resistance of 73 ohms, but when close to the ground, it varies between 60 and 100 ohms as shown in Fig. 45. Thus, if the wire is broken at the centre it can be fed from a cable having a characteristic impedance of the same value, as the cable will then be correctly terminated. A balanced or twin cable is preferable to a single core or coaxial cable, though the latter can be used. As mentioned in Chapter 4, a half wave dipole can be fed from 600 ohm lines and matched by three methods which were discussed and illustrated by the diagrams of Fig. 39 (a - c). Provided the masts are high enough to allow a half wave line to hang clear of the ground, a half wave tuned stub is quite useful, as adjustments, though critical, can be carried out close to the ground. For easiest matching, however, it is best to employ matching stubs as any unpredictable effects are automatically taken into account. The procedure for using these stubs is as follows:-

(1) Measure the standing waves on each feeder as close as possible to the aerial and note the positions of current maxima. If these positions are not opposite one another on the lines, then the top section of the aerial is unbalanced (possibly due to odd effects) and must be adjusted by lengthening or shortening one side until the currents are opposite. Note carefully the final position of the current maximum.

(2) Move up or down the line a quarter wavelength and measure current minimum.

(3) Calculate the standing wave ratio.

(4) Obtain from the curves of Fig. 38 the length and position of the matching stub required, choosing that type of stub (i.e. open or closed) which can be fitted in closest to the aerial.

(5) Instal this stub.

(6) Check that the final standing wave ratio is less than 10% and re-adjust the stub slightly if necessary.

(ii) Quarter wave line matching (Fig. 39 (c)) can be used if desired but it offers no substantial advantage over the method just described, except that it may be possible to erect reasonably accurately matched aerials by its use without the aid of a standing wave meter, but similar results can be achieved more easily by the use of a folded wire dipole.

Folded Wire Dipoles.

8. (i) Fig. 46 (a - e). A recent development in dipoles is the use of a number of wires close together, fed in series, with the object of raising the input impedance and at the same time broadening the frequency response. In Fig. 23 (b) it will be seen that the adjacent half wave currents are in opposite directions, but if one half wave is bent round until parallel with the other the currents will then flow in the same direction, and since the wires are only a very small fraction of a wavelength apart they may be regarded as one wire, having increased capacity and lowered inductance per unit length, and as the two ends are at the same potential and have the same polarity there is no objection to their being joined together, the aerial thus forming a complete loop half a wavelength long, fed on one side at the centre, as shown in Fig. 46 (a). The polar diagrams and performance will be identical with those of a single wire dipole, but a large change has taken place in the radiation resistance.

(ii) Depending on the actual radiation resistance (See Fig. 45) which varies between 98 and 58 ohms, a single wire dipole fed with a current of 1 ampere will radiate between 58 and 98 watts of power, but by folding the wire into a complete loop this single ampere would flow in each wire, and would thus make two contributions to the radiated field. The loop would thus be equivalent to a single wire aerial fed with 2 amperes. Since the power radiated is proportional to the resistance of the aerial and to the square of the current (I^2R); for the same current a folded wire aerial would radiate four times as much power as a single wire aerial, but as the current is still 1 ampere then the radiation resistance must be increased by four times, i.e. to between 232 and 392 ohms.

(iii) In a similar manner, the three wire aerial shown in Fig. 46(b) would have a radiation resistance 3^2, i.e. nine times that of a single wire aerial. Thus its radiation resistance, again depending on height, will be between 522 and 892 ohms. A case of particular interest when using this aerial is when it is erected half a wavelength above ground. From Fig. 45 the radiation resistance is 68 ohms for a single wire dipole, and so for the three wire dipole will be 612 ohms. This aerial could thus be fed directly with negligible mismatch from 600 ohm feeders.

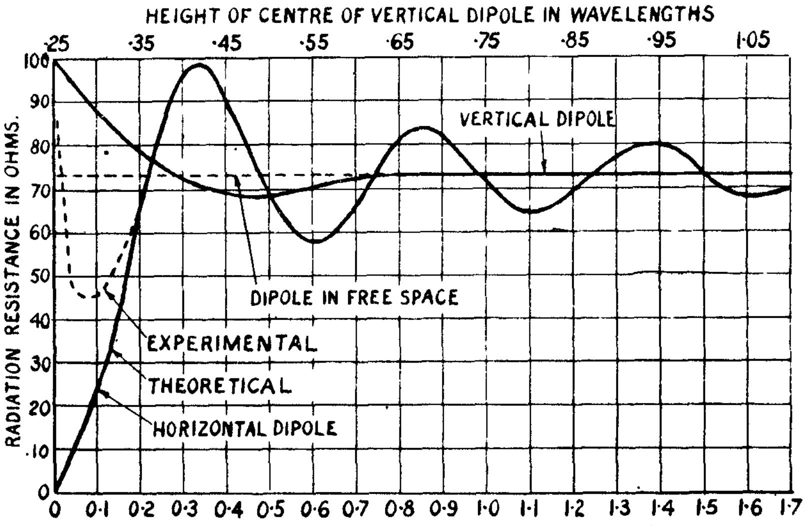
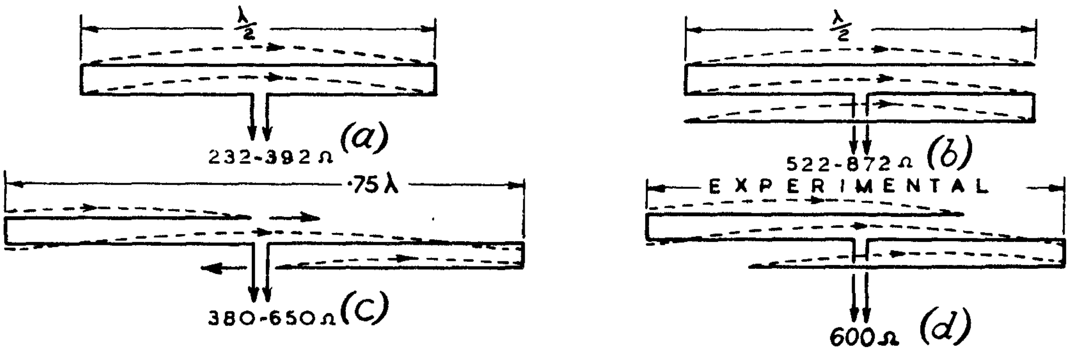


FIG. Nº 45



FOLDED WIRE DIPOLES
FIG. Nº 46.

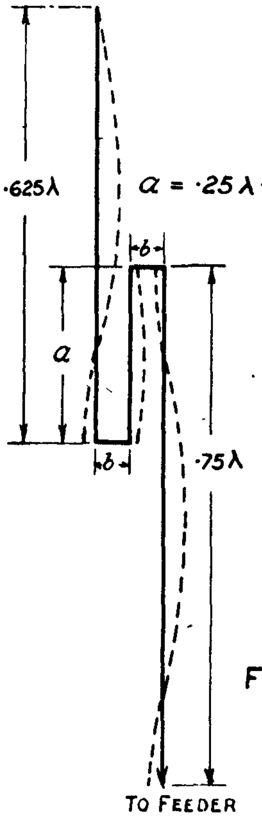


FIG. Nº 47

FRANKLIN UNIFORM

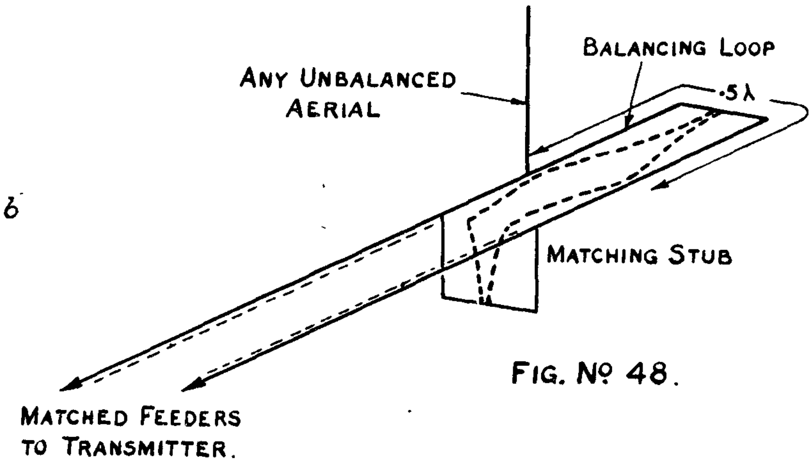


FIG. Nº 48.

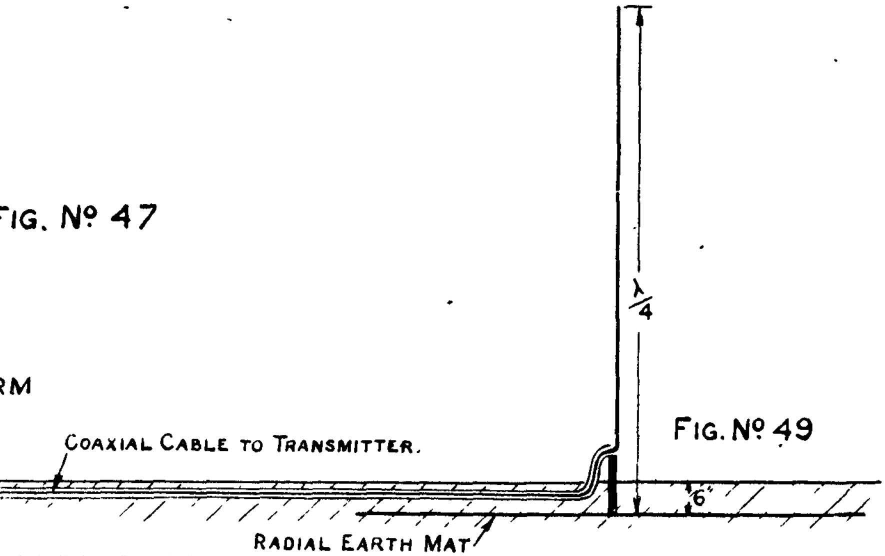


FIG. Nº 49

DOTTED LINES SHOW CURRENT DISTRIBUTION.

(iv) Fig. 46(c) shows another method of folding the wire. In this arrangement a wavelength and a half of wire is doubled back on itself from each end, so that the overall aerial length is three quarters of a wavelength, but the loop instead of being closed is now in two halves. Tracing the current distribution along this loop, it will be seen that in some parts the currents flow in opposite directions and consequently some of the wire will not radiate any energy, due to cancellation from the opposite wire.

(v) Thus, as might be expected the radiation resistance of this aerial is less than that obtained from the three wire aerial. The actual value is somewhere between 380 and 650 ohms depending, of course, on the height above ground. It will be noted that both this aerial and the three wire aerial have a total wire length of 1½ wavelengths, and that the difference in radiation resistance is due only to the arrangement of this length. If the aerial in Fig. 46 (c) were to be shortened by pulling in the direction of the arrows, then eventually when the indicated ends came level with the folds it would be the three wire aerial of Fig. 46 (b), but since in the initial position it has a radiation resistance between 380 and 650 ohms, and in the final arrangement a radiation resistance between 522 and 872 ohms, it follows that where a dipole is required at some height above ground other than half a wavelength, then by experimenting with the overall length of the dipole, while maintaining the total wire length at 1½ wavelengths (Fig. 46(d)), it will be possible to adjust the radiation resistance to a figure very close to 600 ohms and thus avoid the necessity for stub matching.

(vi) At the same time as this simplicity of matching is achieved the decreased characteristic impedance of the folded aerial, caused by the increased capacity and lowered inductance per unit length, broadens the tuning as in the cage aerial (paragraph 2). Thus an aerial of this type may be used over a frequency band of ± 7% on the optimum frequency, without the standing waves produced by the mismatch at the aerial exceeding a 2 : 1 ratio. Owing to the broad frequency response characteristic the resonant length of folded aerials is hard to determine, but initial experiments with a half wave three wire aerial at half a wavelength above ground indicate that the resonant length of the aerial corresponds closely to curve (a) in Fig. 41. The spacing between the wires is not critical and insulators type 375 providing 6" spacing can be used, for frequencies above 10 m.c/s, and type 344 giving 10" spacing for frequencies below 10 m.c/s. 100 lbs/mile wire should be used for the vertical feeders and the aerial itself.

Kooman's Arrays.

9. (i) The schematic arrangement of a 2 bay 2 tier aerial is shown in Fig. 26(a); this aerial is rather complex to rig and erect, as suspension catenaries and the lengths of all elements and rigging wires must be accurately calculated if the array is to hang correctly. The mathematics of this work are quite difficult and beyond the scope of this handbook.

(ii) The aerial is generally matched by means of stubs and the procedure for the 2 bay 2 tier aerial of Fig. 26(a) is as follows:-

(1) Measure the standing waves on the sections marked (a) (on a 4 bay aerial there will be four (a)'s)

(2) From the curves of Fig. 38(a) calculate the length and position of the stub required using the scale of Fig. 38(b) to obtain the lengths in feet.

(3) Instal these stubs

(4) Measure the standing waves on the main feeder (b) (on a 4 bay aerial there will be two (b)'s)

(5) Calculate and install an open or closed stub as required to match the feeder at this point. (On a 4 bay aerial a further stub is required at the junction of two (b)'s)

(6) Check residual standing waves and if greater than 10% adjust the stub as necessary to reduce them to below this figure.

(iii) Matching can also be carried out using the quarter wave matching lines discussed in Chapter 4, paragraph 7.

(iv) The length of the horizontal elements of this aerial is fairly critical and difficult to determine precisely, owing to the coupling to other elements and the proximity of rigging wires etc. When a reflecting curtain is used to make this aerial uni-directional, the length of both driven and parasitic elements should be made the same, and resonant lengths can be worked out from the appropriate curve of Fig.41 The tuning of the parasitic elements can be carried out most easily by bringing down an open wire line three quarters of a wavelength long from the lowest elements, and by adjusting the shorting bar at the bottom of the line to give maximum forward radiation. As the tuning of the reflectors will react on the driven curtain, the above adjustments should be carried out at low power before beginning the main matching described above. Where a broad frequency band characteristic is required cage type elements can be used suitably shortened to bring them into resonance as described in paragraph 2.

Sterba Arrays.

10. (i) With this type of aerial as shown in Fig. 26 (c - d) there is only one feed point, and any mismatch at this point is removed by matching stubs or quarter wave line. In Arctic climates where ice formation on an aerial may render it unserviceable, this aerial has the advantage of being a completely closed loop, so that low frequency or direct currents may be passed around the aerial to heat it and melt ice formation without interfering with transmission on the operating frequency.

Franklin Uniform Aerial.

11. (i) As this aerial is an arrangement of vertical dipoles, mast height will usually limit the number of folds possible to one or two. The current distributions are shown schematically in Fig. 26(e) and practical details in Fig. 46. It will be seen from Fig. 46 that the first length from the feeder line is .75 wavelength, the top section .625 wavelength, and that the fold is a quarter wavelength including the cross pieces "b", which are usually about 1' long, used to connect the fold. These lengths are electrical lengths i.e. the physical length of the wire will be shorter than this, the amount depending on the frequency and rigging, proportionate lengths should be calculated from the appropriate curve of Fig. 40, but the percentage shrinkage for the .75 wavelength section should be taken from (c). This aerial provides an entirely unbalanced load for the feeder system and so can be fed easily from coaxial cable using a suitable matching transformer. With open wire lines, however, a half wavelength phasing loop and an impedance matching stub must be used to provide a matched and balanced load for the lines. The methods of doing this are discussed in the next paragraph as they hold for all unbalanced aerials.

Vertical Aerials.

12. (i) All these aerials provide an unbalanced load if fed from the base, and as open wire transmission lines must be balanced for efficient operation, arrangements must be made to apply the load to both feeders equally. The method of doing this is shown diagrammatically in Fig. 48. As mentioned in Chapter 4 when discussing transmission lines, conditions on the line repeat at half wave intervals but with reversed sign, so that a half wavelength of line or a single wire will act as a 1 : 1 transformer with 180° phase angle between input and output. By connecting a half

wavelength of wire folded back on itself for convenience and suppression of radiation, between the point of connection of the aerial, and the unconnected end of the feeder, the reversed voltage and the load at the aerial point is reflected into the opposite feeder thus placing an equal load on each line.

(ii) As it is unlikely that the aerial will be of the correct radiation resistance for there to be no standing waves on the feeders, it is necessary to use a matching stub as shown in Fig. 48, but the type and position of the stub will depend upon the aerial being used. The procedure to adopt when setting up an aerial fed in this manner is as follows:-

(1) Measure the standing waves on both the main feeders and note any difference in distance from the aerial of the current maxima. Taking the current maximum on the aerial side of the feeder as a fixed point, adjust the length of the phasing loop until the current maximum on the other feeder is exactly opposite.

(2) Measure the maximum and minimum values of the standing waves and calculate the length and position from the current maximum of a suitable stub.

(3) Install this stub and check that the standing waves are less than 10%.

(4) Readjust the stub slightly as necessary to reduce standing waves to this figure or below it.

Vertical Aerials Fed by Coaxial Cable.

13. (i) For all lengths of vertical aerials, except a quarter wavelength (and possibly 3/4), some form of matching device will be necessary to match low impedance coaxial cable to the aerial, but in the case of the quarter wave, the natural impedance at the base of the aerial is 36 ohms plus a few ohms of dead loss and earth resistance say 40 - 45 ohms in all. Thus a coaxial cable of this impedance such as Uniradio No. 5 or Uniradio No. 37 can be connected through a junction box type 12 (see Appendix B) directly to the base of the aerial without any matching device. This arrangement forms a very simple and convenient system for low and medium power transmitters, and is used in the Service for providing many classes of communication. The arrangement is shown diagrammatically in Fig.49 and the resonant length of the aerial as taken from curve (c) of Fig. 41 must include the height of the support of the radial earth mat. Where mast height limits the aerial the top may be turned over horizontally for up to one third its length without the polar diagram becoming very greatly distorted, but the lower section must remain vertical. If a broad band characteristic is required then a quarter wave cage can be used (paragraph 2) and the length taken from curve (d) Fig. 31

Notes on Rigging Aerials.

14. (i) The following list of notes gives the main points to be borne in mind when rigging aerials.

(1) As far as possible avoid having any large pieces or long lengths of metal anywhere in the neighbourhood of the aerial, unless they are performing some electrical function, i.e. take an imaginary Xray view of the site and make certain that all pieces of wire or metal are doing essential work. Where steel guys or triatics are necessary they should be broken up with insulators at intervals of 12'

(2) Halyards and triatics should, where possible, be made of rope, with suitable counter weights attached, to allow for expansion and contraction due to changes in the weather.

(3) Where wooden masts are used on high power stations wire halyards should be avoided, as there is the possibility that the wire length may be resonant at a frequency in use and thus set the tower on fire. For the same reason lightning conductors, if fitted, should be broken up into 12' lengths with a gap of about half an inch between the lengths.

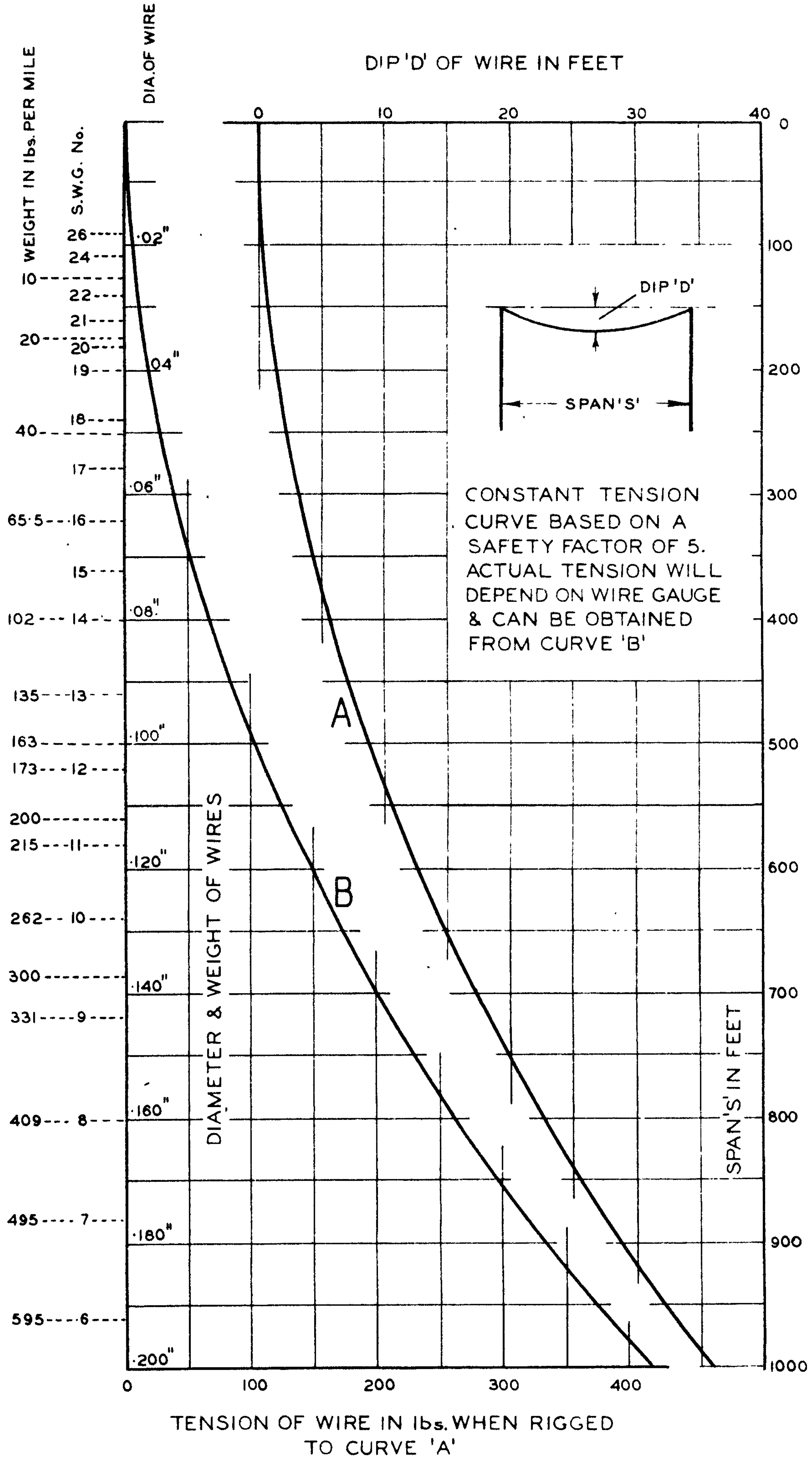
(4) Curve A of Fig. 50 provides information on the dip to be allowed when using single hard drawn copper wires over varying lengths of span, and curve B the tension which will be developed in wires of varying diameter when pulled up to the dip shown by curve A. This tension specifies the counter-weight required on the halyard of the aerial, and holds for all arrangements of wire and rope etc. where the full tension is at some point taken by the copper wire, e.g. the counter-weight for a dipole with the top section of 100 lbs/mile wire is 65 lbs. These curves are based on an approximate safety factor of five, and the left hand scale of curve B provides corrolation between wire diameter S.W.G. number and weight in pounds per mile.

(5) Ensure that all insulators are capable of carrying the electrical and mechanical stresses imposed on them, and that the rigging as a whole is as simple as possible.

(6) Do not neglect to grease pulleys before finally erecting them.

(7) The life of untarred rope can be greatly lengthened, and the expansion and contraction with weather changes similarly reduced by soaking the rope in old lubricating oil for 24 hours.

CURVES RELATING, DIP & SPAN, WIRE SIZE & TENSION FOR HARD DRAWN COPPER WIRES



CONSTANT TENSION CURVE BASED ON A SAFETY FACTOR OF 5. ACTUAL TENSION WILL DEPEND ON WIRE GAUGE & CAN BE OBTAINED FROM CURVE 'B'

FIG. No 50

APPENDIX "A"

Interservice Radio Frequency Cables.

This list gives the interservices reference, pattern numbers, and technical data of most of the coaxial cable used by the Services.

The cables are divided into two Categories 1 and 2. Category 1 cables should be used wherever possible. Category 2 cables are subject to certain restrictions e.g. supply difficulties, special applications, unsuitability of design etc., but may be used when no suitable cable can be found in Category 1. Cables not listed in either of these groups should not be demanded without reference to high authority.

The responsible authorities are as follows:-

Ministry of Supply.

Controller of Physical Research and Signals Developments.
Iron Trades House,
Grosvenor Place, S.W.1.

Admiralty.

Admiralty Signals Establishment.
c/o G.P.O., LONDON.

Ministry of Aircraft Production.

Director of Communications Development,
Thames House,
Millbank, S.W.1.

The following R.A.F. cables have been superseded.

Unilocapmet.	No. 1	5E/2032	by Uniradio No. 18
"	" 2	5E/2057	has no direct replacement but is approximately equivalent to Uniradio No.18
"	" 3	5E/2070	) by (Uniradio No. 4
"	" 4	5E/2046	) (Uniradio No. 5
"	" 5	5E/2058	by Uniradio No. 6
Dulocapmet	" 1	5E/2033	by Duradio No. 20
"	" 2	5E/2045	by Duradio No. 11
"	" 3	5E/2050	has no direct replacement but is approximately equivalent to Duradio No. 28 5E/2228 and no difficulty should arise if the latter is used.

As will be seen from the list there is no apparent difference between Uniradio Nos. 4 and 5, but No. 4 has a pure Polythene core and as polythene is in short supply, Uniradio No. 5 should be used for normal purposes.

APPENDIX "A"

INTERSERVICE RADIO FREQUENCY CABLES.

Type No. of Service Cable.	Army Type Ref.	Naval Patt. No.	R.A.F. Stores Ref.	Zo ohms.		Relative Wave Velocity		Loss db/100' 5 mc/s.	Capacity pF/ft.	Dielectric	Inner Conductor	Outer Conductor		Outer Covering	Overall Dia. Inches.	REMARKS
				Min.	Max.	Min.	Max.					Description	Inner Dia.			
CATEGORY 1.	ZC-		5E/													
Uniradio No. 1	9398	13801	2201	70	80	.65	.69	0.4	21	Solid	1/0.056"	T.C.W.Braid	.33"	Vinyl resin sheath	.45	Flexible.
No. 2	9400	13802	2202	70	80	.65	.69	0.4	21	Solid	1/0.056"	Lead Sheath	.33"	Served	.65	More stable characteristics than Armoured type Uniradio 2.
No. 3	9402	13803	2203	70	80	.65	.69	0.4	21	Solid	1/0.056"	Lead sheath	.33"	Steel wire armouring	.945	
No. 4	9396	13804	2204	43	50	.65	.69	0.6	35	Solid	7/0.032"	T.C.W.Braid	.285"	Vinyl resin sheath	.450	Flexible.
No. 5	9397	13805	2205	39	50			0.6	37	Solid	7/0.032"	T.C.W.Braid	.285"	Do.	.405	Similar to Uniradio No.4 but less stringent specification.
No. 8	9404	13808	2208	95	107	.94	.98	0.14	10	Air. Discs at intervals.	1/0.128"	Lead Sheath	.75"	Steel tape armouring	1.39	Very low loss
No. 9	9405	13809	2209	70	80			0.2	14	Do.	1/0.103"	Copper strips & steel tape	.375"	Lead covered & armoured.	1.13	Very low loss cable - mechanically strong.
No. 10	9403	13810	2210	64	78			0.15		Solid	1/0.144"	Lead sheath	.80"	Served	1.25	
No. 21	9399	13821	2221	72	77	.65	.69		21	Solid	1/0.056"	T.C.W.Braid	.33"	Vinyl resin sheath	.45	More stringent specification than Uniradio 1.
No. 24	9420	13824	2224	70	80			0.2	14	Air. Discs at intervals.	1/0.103"	Copper strips & steel tape	.375"	Lead	.65	Unarmoured Uniradio No.9
No. 25	9401	13825	2225	70	80	.65	.69	0.4	21	Solid	1/0.056"	Lead Sheath	.35"	None	.45	Unserved Uniradio No.2
No. 31		13831	2231	90	100			0.55		Solid		T.C.W.Braid	.29"	Vinyl resin sheath	.40	Low capacity.
No. 32		13832	2232	67	77			1.3		Solid	1/0.022"	T.C.W.Braid	.128"	Vinyl resin sheath	.23	Smallest solid dielectric cable
No. 33		13833	2233	67	77			1.3		Solid	1/0.022"	Lead Sheath	.128"	Lead Sheath	.188"	
No. 37		13837	2237	39	50	.65	.69	0.6	37	Solid	7/.032"	Lead Sheath	.285"	Served	.61	
Duradio No. 13	9411	13813	2213	88	102	.64	.69	0.5	22	Solid	7/0.032"	Lead Sheath	.475"	Served	.815	High characteristic stability.
No. 26	9407	13826	2226	93	105	.64	.69	1.1	16	Solid	1/0.029"	Lead Sheath	.168"	None	.28	Thicker sheath and unserved Duradio 16.
No. 29	9426	13829	2229	120	150	.64	.69	0.5	11	Solid	7/0.032	None	.58	None	.58	Twin for use where screening not desirable.
No. 30	9427	13830	2230	115	145	.64	.69	0.7	12	Solid	7/0.022"	None	.40	None	.40	A smaller type Duradio No.29

Type No. of Service Cable.	Army Type Ref.	Naval Patt. No.	R.A.F. Stores Ref.	Z_0 ohms.		Relative Wave Velocity		Loss db/100' 5 mc/s.	Capacity pF/ft.	Dielectric	Inner Conductor	Outer Conductor		Outer Covering	Overall Dia. Inches.	REMARKS
				Min.	Max.	Min.	Max.					Description	Inner Dia.			
CATEGORY 2.	ZC-		5E/													
Uniradio No. 6	9414	13806	2206	90	110			0.22	13	Spiral thread in tube.	1/0.036"	T.C.W.Braid	.25"	Vinyl resin sheath	.365	Flexible - low capacity.
No. 7	9418	13807	2207	102	118	.89	.95	0.15	10	Air. Discs in insulating tube.	1/0.128"	Copper tapes	.88"	Flexible waterproof.	1.14	Flexible - low loss - low capacity.
No.17	9417	13817	2217	63	77	.65	.68	0.2	22	Solid	7/0.048"	T.C.W.Braid	.8"	Vinyl resin sheath	1.00	Similar to Uniradio No.10 - to be used only when cable requires to be twisted.
No.18	9415	13818	2218	73	84			0.45	13	Fins of Star section in tube.	7/0.022"	T.C.W.Braid	.53"	Flexible waterproof	.45	Flexible. Cheaper and lower quality
No.19	9416	13819	2219	73	84			0.45	18	Fins of Star section in tube	7/0.022"	T.C.W.Braid	.33"	None	.360	Unsheathed Uniradio No.18
No.23	9419	13823	2223	70	80			0.2	14	Air. Discs at intervals.	1/0.056"	Lead sheath	.55"	Steel tape armouring	1.19	Not so Strong as Uniradio No.9 otherwise can be used in lieu.
No.27	9424	13827	2227	70	80			0.2	14	Air. Discs at intervals	1/0.155"	Lead sheath	.55"	None	.710	Unarmoured No.23 type.
Duradio No.11	9409	13811	2211	88	102	.64	.69	0.5	16	Solid	7/0.032"	T.C.W.Braid	.475"	Vinyl resin sheath	.62	Flexible high voltage twin.
No.12	9410	13812	2212	80	102			0.65	20	Solid	7/0.032"	T.C.W.Braid	.475"	Vinyl resin sheath	.62	Less stringent specification than Duradio No.11
No.16	9406	13816	2216	93	103	.64	.69	1.1	16	Solid	1/0.029"	Lead Sheath	.168"	Lapping of impregnated cotton	.265	Smallest twin cable.
No.20	9421	13820	2220	135	165			0.8	9	Fins of Star section in tube	7/0.022"	T.C.W.Braid	.65"	Flexible waterproof	.77	Flexible, low capacity. Use not encouraged.
No.28	5425	13828	2228	93	103	.64	.69	1.1	16	Solid	1/0.029"	T.C.W.Braid	.168"	Flexible waterproof	.290	Flexible twin.

NOTES.

T.C.W. = tinned copper wire

P.C.W. = plain copper wire

All inner conductors are P.C.W. Dimensions and number of strands are shown under heading "Inner Conductor".

APPENDIX B

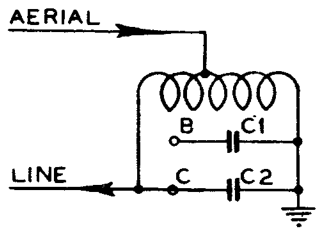
R.A.F. PATTERN MATCHING UNITS

TYPE 2

REF. No. 10A/11551. RANGE $\left.\begin{matrix}2{\cdot}5-4\\3{\cdot}5-10\end{matrix}\right\}$ MC/S TRANSMITTING OR RECEIVING

USED TO MATCH ¼ λ VERTICAL AERIAL TO 75Ω COAXIAL CABLE. CAPABLE OF HANDLING UP TO 500 WATTS.

THEORETICAL DIAGRAM



C1 — ·0004 MFD.
C2 — ·0003 MFD.

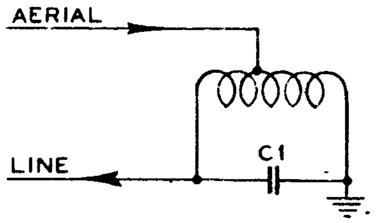
2 - 4·5 MC/S CONNECT B & C
3·5 - 10 MC/S AS SHOWN

TYPE 7

REF. No. 10A/11981. RANGE 8 — 17 MC/S TRANSMITTING OR RECEIVING

USED TO MATCH A ¼ λ VERTICAL AERIAL TO 75Ω COAXIAL CABLE. CAPABLE OF HANDLING UP TO 500 WATTS.

THEORETICAL DIAGRAM



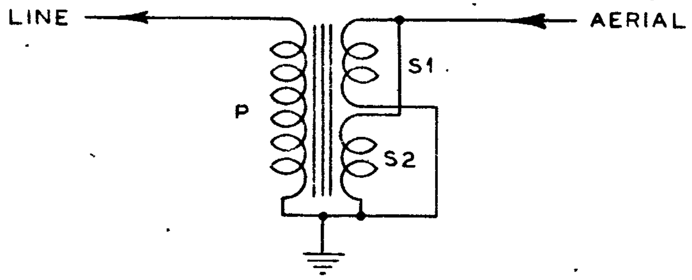
C1 — ·0001 MFD

TYPE 18

REF. No. 10A/12368. RANGE 16 — 500 KC/S RECEPTION ONLY

USED TO MATCH LOW FREQUENCY AERIALS TO 75Ω COAXIAL CABLES

THEORETICAL DIAGRAM

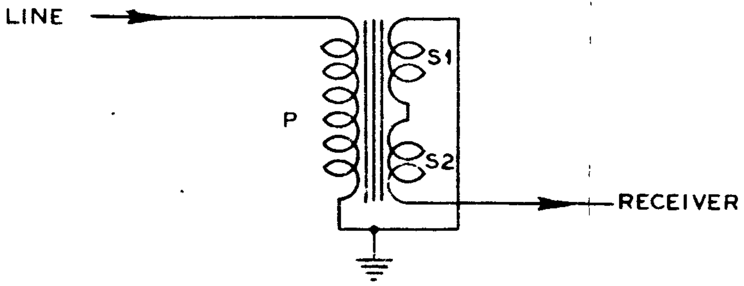


TYPE 19

REF. No. 10A/12369 RANGE 16 — 500 KC/S RECEPTION ONLY

USED TO MATCH 75Ω COAXIAL CABLE INTO A RECEIVER HAVING A HIGH INPUT IMPEDANCE AT LOW FREQUENCY — i.e. R 1084.

THEORETICAL DIAGRAM

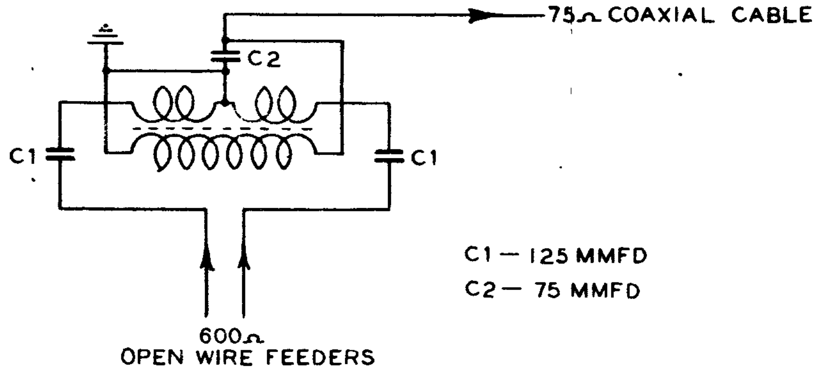


TYPE 68

REF. No. 10A/12500 RANGE 2·5 — 20 MC/S RECEPTION ONLY

USED TO MATCH 600Ω BALANCED LINES (i.e. OPEN WIRE FEEDERS) TO 75Ω COAXIAL CABLE.

THEORETICAL DIAGRAM



C1 — 125 MMFD
C2 — 75 MMFD

TYPE 3

REF. No. 10A/11750. RANGE 5 — 20 MC/S. OBSOLETE. REPLACED BY TYPE 68

TYPE 10

RENDERED REDUNDANT BY THE INTRODUCTION OF THE THREE WIRE DIPOLE (AIR MINISTRY DRAWING No. WT 50346) WHICH ALLOWS 600Ω FEEDERS TO BE FED DIRECT INTO THE AERIAL

TYPE 11

REF. No. 10A/12147. RANGE 5 — 20 MC/S. NOT IN PRODUCTION. 300Ω BALANCED LINES INTO 75Ω COAXIAL CABLE.

APPENDIX "C"

R.A.F. Pattern Junction Boxes.

Type 3. Reference 10A/11552 Indoor Use.

Providing straight through connection through a sleeve adaptor (10A/11549) to a socket type 68 (10A/11559)

A 4" square wall mounting, cast brass box, fitted with one sleeve adaptor and one socket type 68. The aerial is terminated, via the coaxial cable, at the box, and flexibility is achieved by allowing any medium power transmitter, or receiver, to be plugged into the socket type 68.

This single unit is now superseded by the type 3 distribution box.

Type 5. Reference 10A/11858 Indoor Use.

Providing a means of feeding the output from transmitters of not more than 2.5 amps current output into coaxial cable.

A 4" square cast brass box, with mounting strip, incorporating two insulators type 48, one socket type 68 and a 0 - 2.5 thermo-ammeter.

The transmitter output may be connected to either of the insulators type 48 and the unit mounted in a convenient position on the transmitter.

Type 12. Reference 10A/12142 Outdoor use.

Providing straight through connection through a sleeve adaptor to an insulator type 48.

A 4" square cast brass box, designed for mounting on to the support of the radial earth type 4, a vertical quarter wave aerial terminating on the insulator type 48.

Type 13. Reference 10A/12652 Indoor Use.

Providing facilities for feeding three receivers from one aerial.

A 4" cast brass box fitted with three sockets type 68 and one sleeve adaptor, and provided with a plate for wall mounting.

Type 16. Reference 10A/12188 Indoor Use.

Providing straight through connection from a socket type 68 to an insulator type 48.

A 4" cast brass box fitted with an insulator type 48 and a socket type 68, and provides a means of feeding the output of medium power transmitters into coaxial feeders.

Similar to the type 5 - but without the thermo-ammeter.

Distribution Boxes.

Type 3. Reference 10A/12652 Indoor use.

Provides five coaxial input channels (sleeve adaptors 10A/11549) and five coaxial output channels (sockets type 56) in a single unit.

A mild steel box and lid, zinc sprayed, with the five adaptors mounted in line at right angles to the five sockets type 56, and designed for wall mounting. This allows any one of the five inputs to be fed to any one of five units - transmitters or receivers.

Mountings.

Type 95. **Reference 10A/12686**

Used in conjunction with distribution box type 3 at receiving sites.

A mild steel plate, zinc sprayed, with five sockets type 68 mounted on it. This unit replaces the lid normally supplied with the box, and provides outlets to two receivers from each aerial input, i.e. ten receivers from five aerials.

For method of terminating small lead sheathed coaxial cable in sleeve adaptors see drawing W.T. 50502 and for flexible cable see drawing W.T. 23852.

Plugs.

Type 160 **Reference 10H/183.**

Used for terminating flexible coaxial cable. This plug fits on the end of Uniradio No. 5 and other coaxial cables of similar size. It plugs into the socket type 56 or 68 mounted on the Distribution and Junction boxes above and also into the input sockets on Receivers such as the R.1084 or R.1188.

Type 161. **Reference 10H/184.**

Similar to type 160 but has a 90° elbow bend.

		REFERENCE NO.	
Insulators Type	1.	10B/465	4" high corrugated white porcelain wit quare metal Base. Used for indoor spacing of transmission lines.
	317.	10B/13284	As for Type 1. Mechanically stron than Type 1.
	5.	10B/1871	Ebonite lead-in type screw mounting. or receivers or low power transmitter leads-in.
	6.	10B/7375	Porcelain corrugated lead-in. For with all power ratings up to 5 k.w.
	8.	10B/7015	Ebonite link type - large) Sma nd medium size aerials.
	9.	10B/1275	Ebonite link type - small)
	17.	10B/6097	Pyrex glass type corrugated 3" long erial Strain type with holes at each end 3" centre
	13.	10B/7652	" " " " 7" " " " " " " " " " 6" centre
	50.	10B/11479	" " " " 12" " " " " " " " " " 10" centre
	19.	10B/9010	Porcelain type with large "skirts". nted on cross arms of feeder poles to carry open wire feeder lines.
	316.	10B/13283	Is mechanically interchangeable with e 19 - but has corrugations in lieu of "skirt" and therefore may be d with 6" spaced lines.
	21.	10B/9115	Two type 20 insulators mounted on metpanel. Large hollow conical lead-in type for all powers.
	40.	10B/6	Small brown glazed porcelain.
	41.	10B/11429	Large " " " $4\frac{1}{2}$" long Used to break up aerial stays or light triatics.
	60.	10B/100	Small white glazed egg shaped. Do.
	228.	10B/572	Porcelain egg shaped 1" long.
	104.	10B/243	Porcelain barrel type $1\frac{3}{4}$" long)
	103.	10B/242	" " " $2\frac{3}{4}$" long) hout holes - also used to break up stays - guys - and triatics.
	102.	10B/241	" " " $5\frac{3}{4}$" long)
	285	10B/13196	8" Porcelain rod with small brass pulys at both ends. May be used on feeder lines.
Marconi type	116.	10B/262	8" Porcelain rod with $3\frac{1}{2}$" Corona rin For high power aerials.
strain	320.	10B/13289	12" Porcelain rod with $4\frac{1}{2}$" Corona ri For high power aerials.
insulators.	286.	10B/13197	12" Porcelain rod with $3\frac{1}{2}$" Corona ri For high power aerials.
	287.	10B/13198	12" Porcelain rod without Corona rin For high power aerials.
	48.	10B/156	Feeder line spacing insulator with holes at 6" centres. Superseded by type 375.
	344.	10B/891	Feeder line spacing insulator 10" sing - i.e. for use with 300 lb/mile wire.
	375.	10B/1194	" " " " 6" " " " 100 lb/mile "
Turnbuckles or strain adjusters.			A D. of W. item - generally acquired Local Purchase Order.
Shackles.			$\frac{1}{2}$" or 3/8" - also acquired by L.P. as required.
Bulldog Grips.			For making fast the ends of wire rope L.P.O. action as required.
Pulley Blocks.		4L/537 4L/536	Single sheath general purpose block wt. load.) For use with hemp or wire rope up to and including 1" c Double sheave general purpose block wt. load.)
Wire - Copper		10B/4581	R.6 3 strands 20 swg enamelled. r temporary or mobile low power aerials.
		5A/1775	100 lb/mile single plain hard dra per wire. For aerials and short distance feeders.

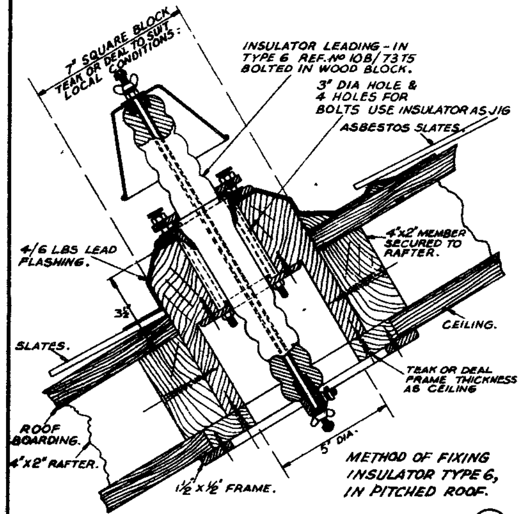
	REFERENCE NO.	ESCRIPTION AND REMARKS
Wire - Copper	5E/1773	200 lb/mile single plain hard drawn copper .) For long feeder lines and high power aerials.
	5E/1772	300 lb/mile single plain hard drawn copper .)
Wire - Galvanised Iron	29/2069	½" circum flexible wire rope 18 cwt. breaki train.)
	29/2071	¾" circum flexible wire rope 38 cwt. breaki train.) For guys, triatics or halyards.
	29/2072	1" circum flexible wire rope 60 cwt. breaki train.)
	29/2073	1¼" circum flexible wire rope 96 cwt. breaki train.)
Thimbles		
Open galvanised	16G/296	For use with 1" circum. rope or wire.
" "	16G/297	For use with 1¼" circum. rope or wire.
Non corrodible steel	28C/6069	For use with ½" circum. rope or wire.
	28C/6072	For use with ¾" circum. rope or wire.
	28C/6074	For use with 1" circum. rope or wire.
Junction Splays	10A/12794	Tinned brass "T" joint for jointing matchirtubs to feeder lines etc.
Spreaders Type 4	10B/195	10' steel with a shackle at each end.
" 38	10B/1210	9' steel with 4 shackles at each end. Upon Rhombic transmitting aerials.
	10B/196	20' long steel with 5 shackles.
" 5	10B/6638	5' long hollow spar.
" 9	10B/173	5" diam. circular aluminium spreaders.) for making cage aerials.
" 10	10B/54	10" diam. circular aluminium spreaders.)
Mats Earth		
Type 1	10B/4151	Copper earth sheet.
" 4	10B/11775	Radial earth of 18, 14 s.w.g. copper wiresch 30' long.
" 7	10B/445	Portable radial earth. 18 flexible wires h 30' with winding spools mounted in box. Clip connection for terminal Type 13.
	10B/6004	Galvanised open wire mesh 15' long 3' wide
Cordage Manilla	32A/48	1" circum. Hawser laid
	32A/50	1½" circum. Hawser laid
	32A/52	2" circum. Hawser laid
	32A/54	3" circum. Hawser laid
Sisal	32A/15	1" circum. Hawser laid and tarred.
	32A/16	1½" circum. Hawser laid and tarred.
	32A/17	2" circum. Hawser laid and tarred.
	32A/19	3" circum. Hawser laid and tarred.
Cord , Kite	32A/7	12 oz/30 Fathoms.
Masts. Type 23	10B/442	78' tubular steel with 3 cigar shaped secons, 250 lbs. Horizontal head load.
	10B/5999	70' Tubular Steel. Tubular Section mechcally weaker than type 23
	10B/10603	27'6" Bakelite Tubular. The sections p inside one another for transportation, and used mainly for receiving aerials.
Terminal Type 13.	10A/196	Used for terminating flexible coaxial cab, provides a screw terminal for connecting aerial wire and metal body, connected to outer conductor of cable, which fits clip on earth mat type 7.

APPENDIX "E"

A Collection of W/T Drawings of General Interest.

W.T.	50502	Termination of unarmoured lead sheathed coaxial cables (small)
	24011	Typical jointing of coaxial cables (flexible)
	23852	Termination of flexible coaxial cables in Matching Units and Junction Boxes.
	50495	Meter for measuring standing waves. General arrangements and details.
	50346	Aerial dipole half-wave three-wire receiving station.
	50191	Aerial arrays. Matching details.
	50457	Typical installation of Matching details for vertical remote aerials (1/8 - 5/8 wavelength)
	50467	Typical installation and matching details for vertical half wave aerial with reflector.
	50477	Typical installation and matching details of vertical quarter wave aerial with reflector.
	50465	Earthed system for vertical quarter wave aerial with reflectors, range 3 - 20 m.c/s.
	50554	Aerial Fishbone, 10 element (suspended between four poles). General arrangement.
	50537	Aerial Fishbone. Rigging details standard.
	50496	Aerial Rhombic four-wire transmitting standard.
	50542	Switch Box for reversing direction of Rhombic Aerial.
	50105	Ground station equipment. Installation details. Four sheets.
	50406	Aerial change-over system for 600 ohm open wire feeders. Typical installations.

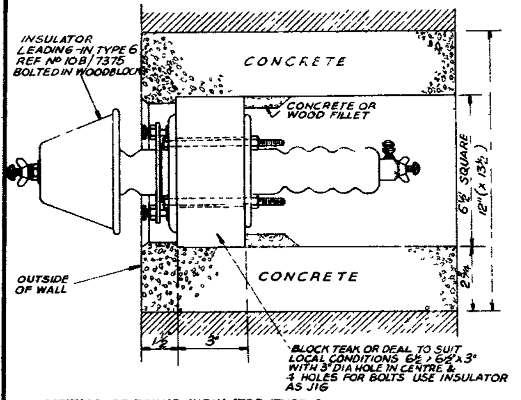
ISSUE 1
DATE -15 / 41
CHANGES:-
DETAILS SHOWN HEREON REPLACE RELEVANT DETAILS ON WT 17630
ISSUE 2 DATE 12.1.43 ADDITIONAL SHEET No. ADDED



METHOD OF FIXING INSULATOR TYPE 6, IN PITCHED ROOF.

SCALE - ¼

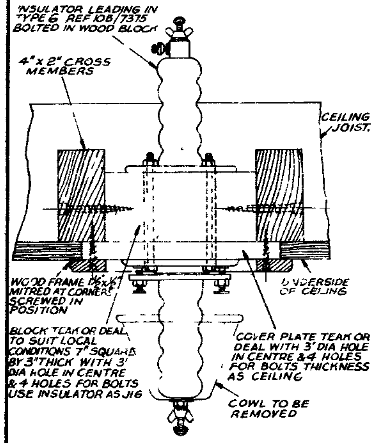
①



METHOD OF FIXING INSULATOR TYPE 6 IN WALL

SCALE - ¼

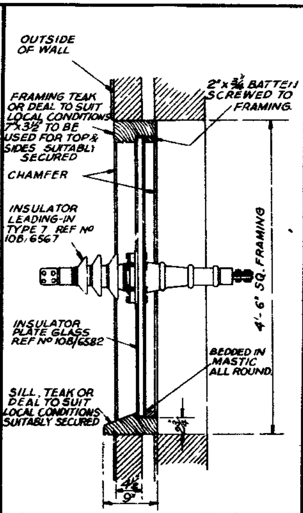
②



METHOD OF FIXING INSULATOR TYPE 6 IN CEILING

SCALE - ¼

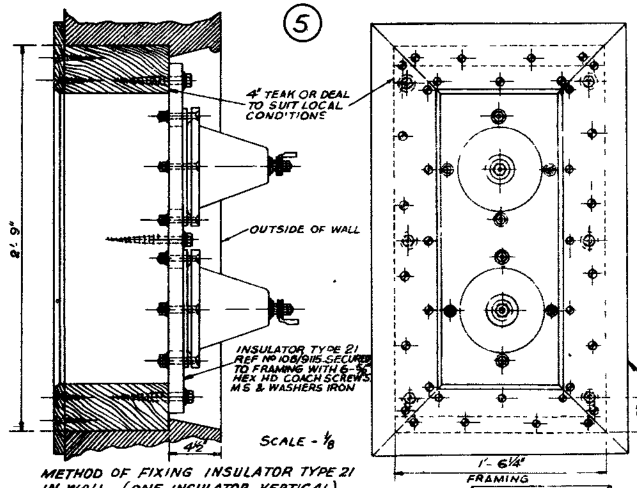
③



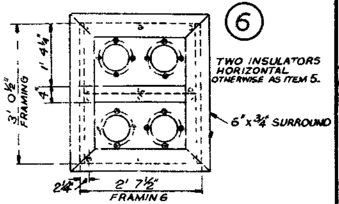
METHOD OF FIXING INSULATORS TYPE 7 & PLATE GLASS IN WALL.

SCALE - 1/16

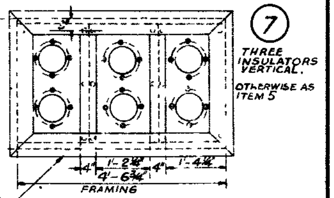
④



METHOD OF FIXING INSULATOR TYPE 21 IN WALL. (ONE INSULATOR VERTICAL).

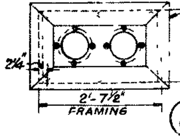


TWO INSULATORS HORIZONTAL OTHERWISE AS ITEM 5.



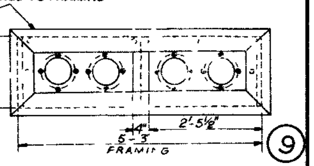
THREE INSULATORS VERTICAL. OTHERWISE AS ITEM 5

6"x¾" SURROUND SCREWED TO FRAMING



⑧

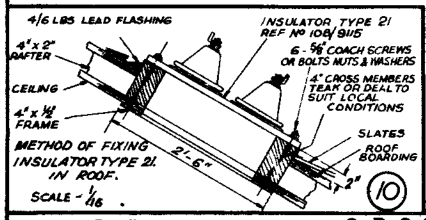
ONE INSULATOR HORIZONTAL OTHERWISE AS ITEM 5



⑨

TWO INSULATORS HORIZONTAL OTHERWISE AS ITEM 5.

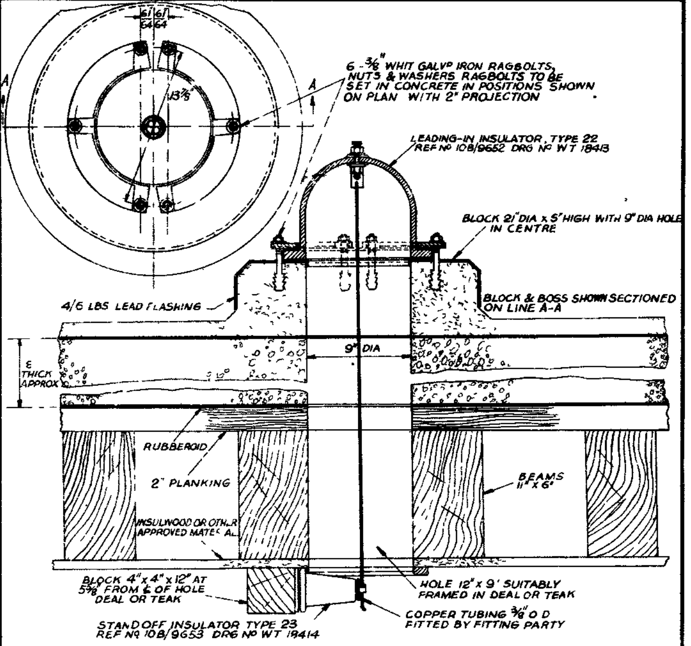
SCALE - 1/24



METHOD OF FIXING INSULATOR TYPE 21. IN ROOF.

SCALE - 1/16

⑩



METHOD OF MOUNTING AERIAL LEAD - IN INSULATOR IN CONCRETE ROOF

SCALE - ⅛

⑪

TITLE:- GROUND STATION EQUIPMENT INSTALLATION DETAILS

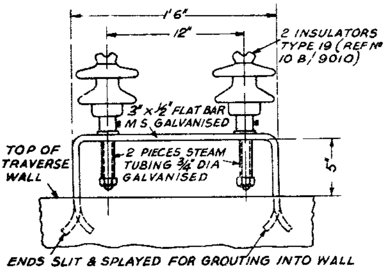
ISSUED BY DIRECTORATE OF COMMUNICATIONS DEVELOPMENT (R.D.C.3) MINISTRY OF AIRCRAFT PRODUCTION

DRAWN	TRACED	CHECKED	DATE	APPROVED	DATE
F.C.T.B.	CONTRACT TRACED	J.G.B.	14/1/41	L.M.B.	15/1/41
				N.H.E.	16/1/41

DRG. No W.T. 50105

SHEET 1 OF 4 SHEETS

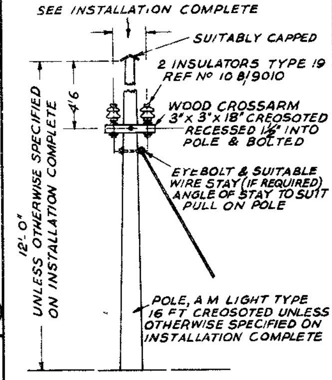
ISSUE 1
DATE 15-1-41
CHANGES
DETAILS SHOWN HEREON REPLACE RELEVANT DETAILS ON WT 17680
ISSUE 2
DATE 12 1 43
ADDITIONAL SHEET No ADDED. NcAA



MOUNTING FOR 2 INSULATORS TYPE 19 FOR SETTING IN CONCRETE

SCALE – ⅛

⑫

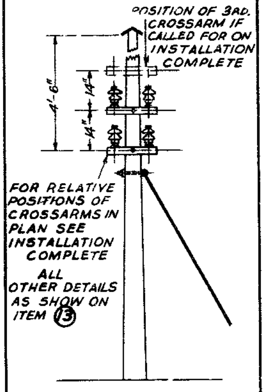


POLE

FOR 1 PAIR OF LINES

SCALE – 1/32

⑬

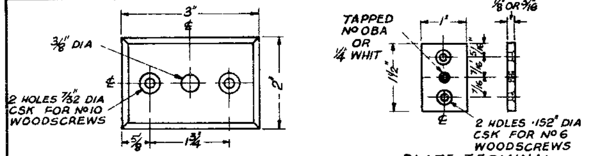


POLE

FOR 2 OR 3 PAIRS OF LINES

SCALE – 1/32

⑭



'A'

BLOCK, WOODEN

TO BE MADE FROM ¾ WOOD ON SITE

SCALE:– ½

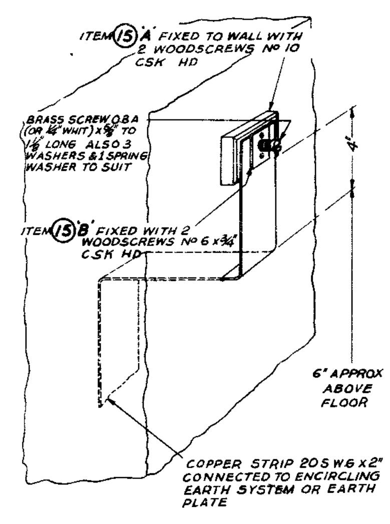
'B'

PLATE, TERMINAL

TO BE MADE FROM COPPER OR BRASS STRIP CALLED FOR ON BUILDING LAYOUT

SCALE – ½

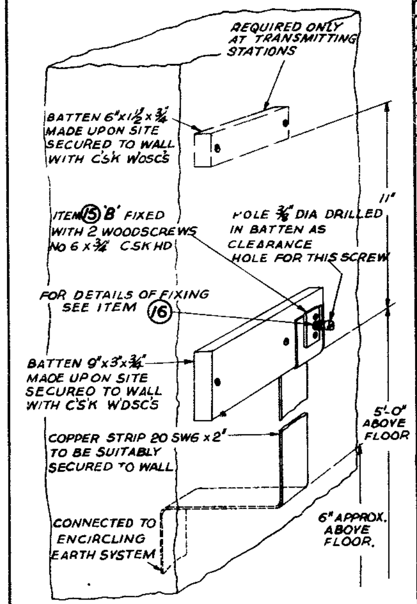
⑮



METHOD OF TERMINATING EARTH STRIP USING BLOCK, WOODEN

SCALE – ¼

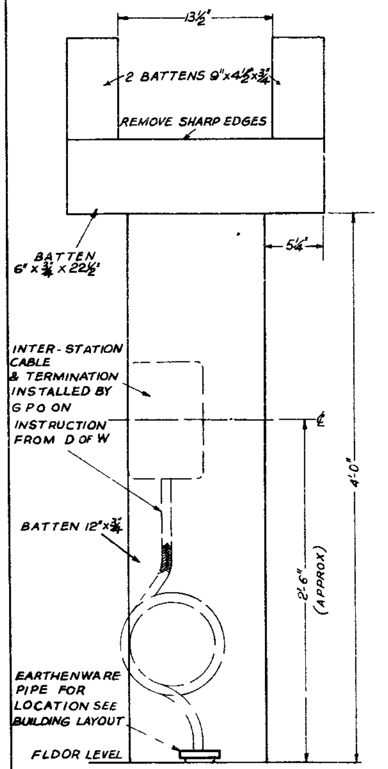
⑯



METHOD OF TERMINATING EARTH STRIP WHEN SWITCH TYPE 6 OR LIGHTNING ARRESTOR IS USED

SCALE – ¼

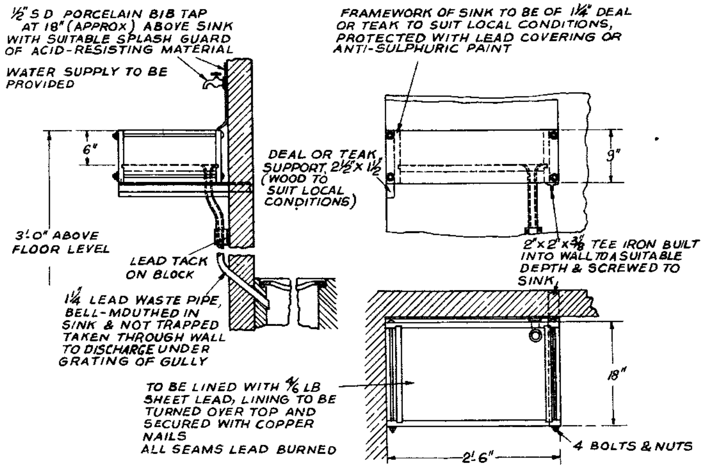
⑰



ASSEMBLY OF BATTENS FOR MOUNTING DISTRIBUTION BOX

SCALE – ⅛

⑱

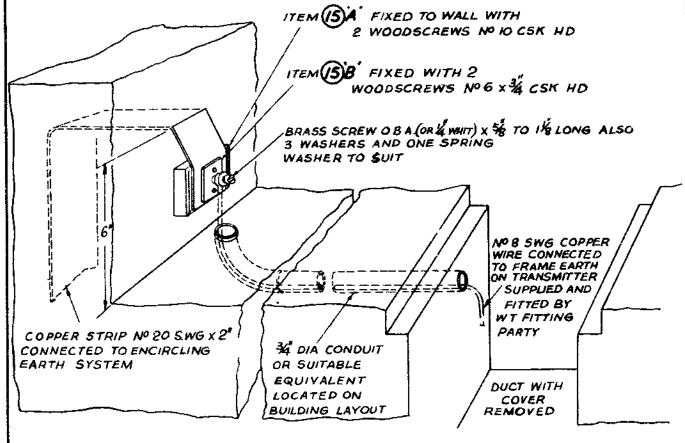


NOTE – FINISH OF ALL METAL PARTS TO BE ACID-RESISTING

SINK, COMPLETE, FOR BATTERY ROOM

SCALE – 1/16

⑲



METHOD OF TERMINATING EARTH STRIP WHEN INTERNAL CONNECTIONS ARE RUN IN CONDUIT

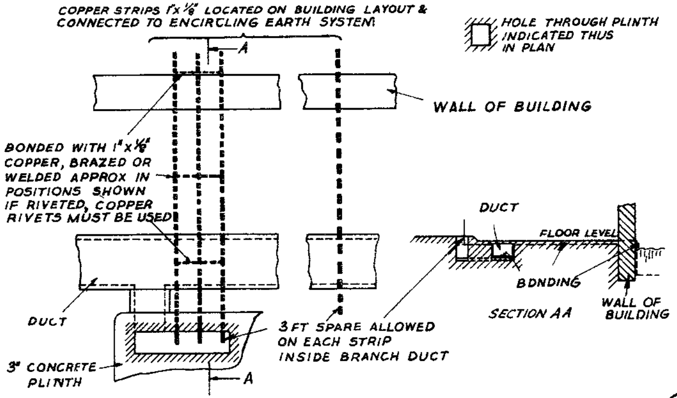
SCALE – ¼

⑳

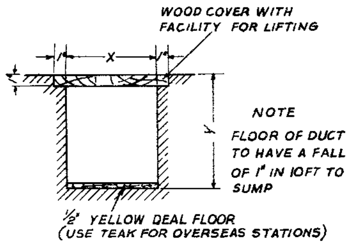
GROUND STATION EQUIPMENT INSTALLATION DETAILS

ISSUED BY DIRECTORATE OF COMMUNICATIONS DEVELOPMENT (R.D.C.3) MINISTRY OF AIRCRAFT PRODUCTION	DRAWN	TRACED	CHECKED	APPROVED	DATE	DRG. No. W T. 50105	SHEET 2 OF 4 SHEETS
	N C A A	CONTRACT TRACED	J. G B	L M G	15 1-41		
				N H E	16 1-41		

ISSUE 1
DATE 22.2.41
CHANGES

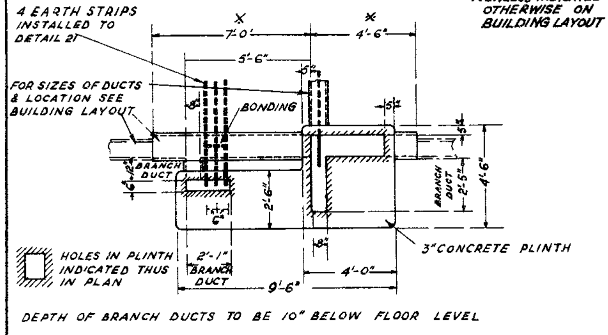


METHOD OF INSTALLING MACHINERY EARTH STRIPS FOR HIGH POWER SHORT WAVE TRANSMITTERS
NOT TO SCALE
(21)

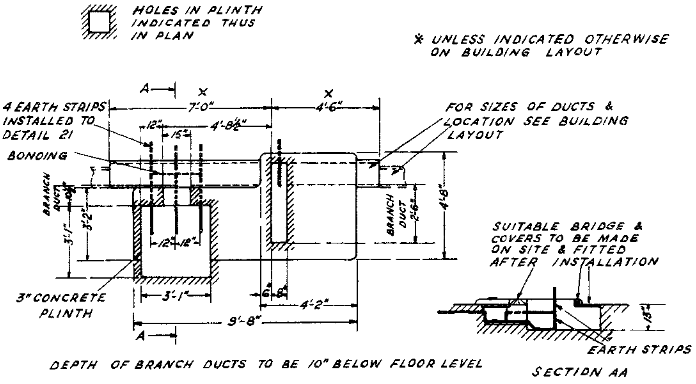


TYPE OF DUCT	DIMENSION	
	X	Y(MIN)
A	8"	10"
B	12"	10"
C	1-6"	12"

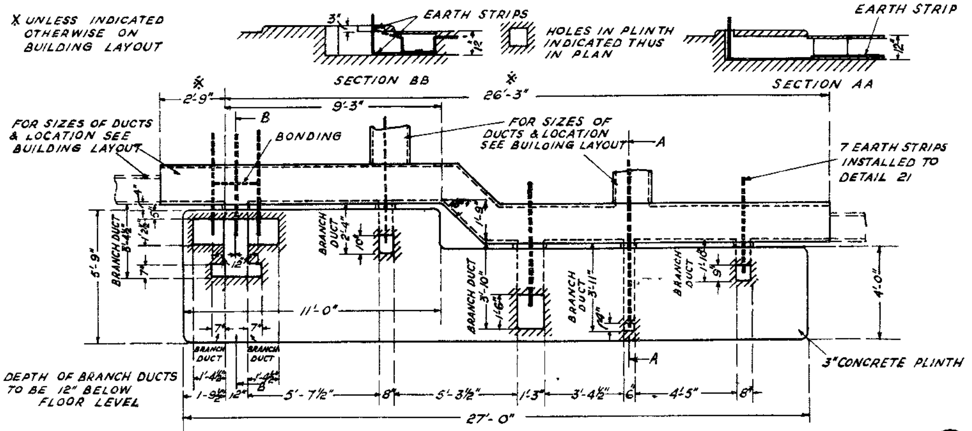
STANDARD MAIN DUCTING
NOT TO SCALE
(22)



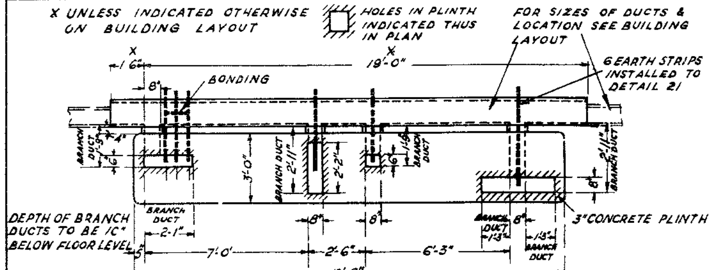
DETAILS OF PLINTH & ASSOCIATED DUCTING FOR SWB8 TRANSMITTER 3RD DESIGN (2 UNIT)
SCALE - ¼" = 1 FOOT
(23)



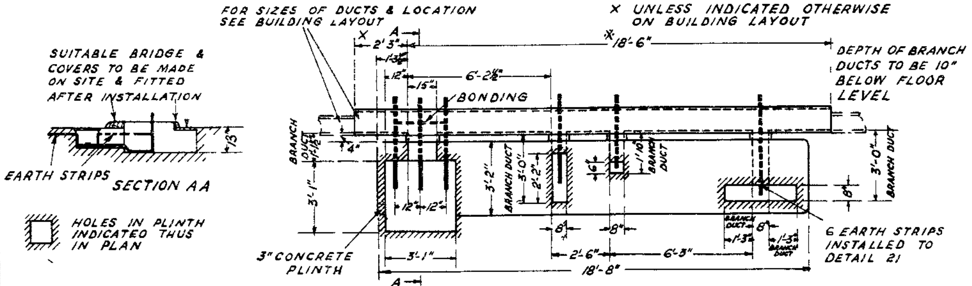
DETAILS OF PLINTH & ASSOCIATED DUCTING FOR SWB8 TRANSMITTER 3RD DESIGN (2 UNIT) EXHAUST AIR COOLED
SCALE .- ¼" = 1 FOOT
(24)



DETAILS OF PLINTH & ASSOCIATED DUCTING FOR SWB10 AMPLIFIER
SCALE .- ¼ = 1 FOOT
(25)



DETAILS OF PLINTH & ASSOCIATED DUCTING FOR SWB8 TRANSMITTER 2ND DESIGN (4 UNIT)
SCALE .- ¼" = 1 FOOT
(26)



DETAILS OF PLINTH & ASSOCIATED DUCTING FOR SWB8 TRANSMITTER 2ND DESIGN (4 UNIT) EXHAUST AIR COOLED
SCALE - ¼" = 1 FOOT
(27)

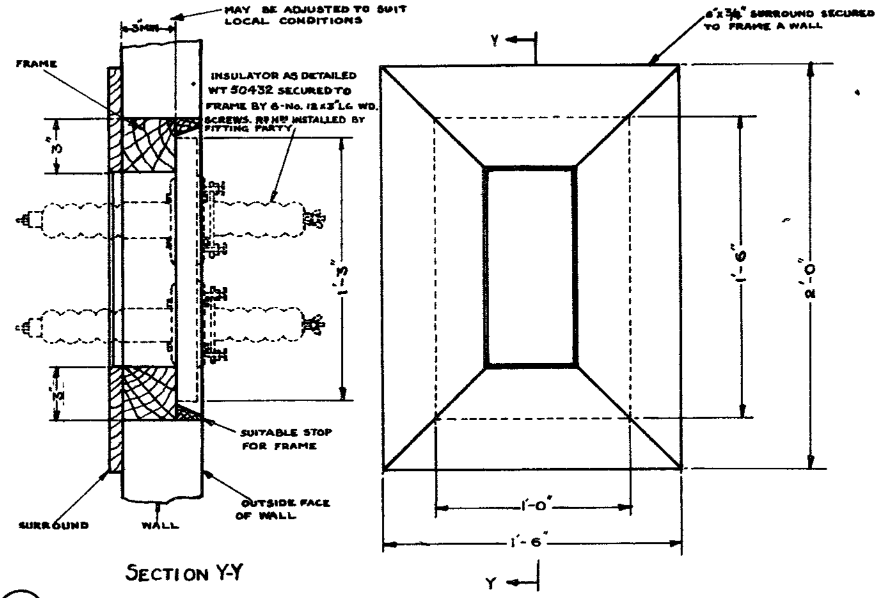
GROUND STATION EQUIPMENT INSTALLATION DETAILS

ISSUED BY DIRECTORATE OF COMMUNICATIONS DEVELOPMENT (RDC3) MINISTRY OF AIRCRAFT PRODUCTION

DRAWN	TRACED	CHECKER	APPROVED	DATE
HCAA	HCAA	GHS	LMG	26/2/41
			SW MOBDAY	26/2/41

DRG. No. W.T 50105
SHEET 3 OF 4 SHEETS

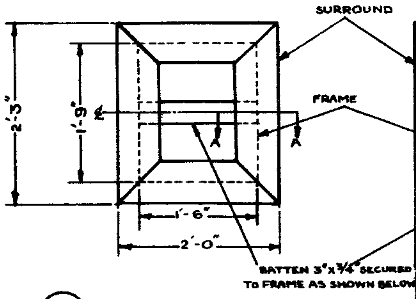
ISSUE Nº 1
DATE 2·5·42.
CHANGES



SECTION Y-Y

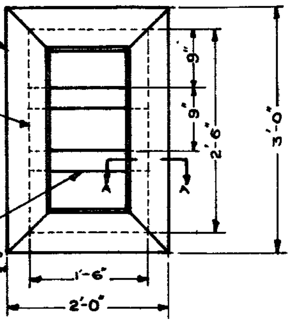
(28) FRAMEWORK FOR MOUNTING 2 TYPE 6 INSULATORS AT 6" SPACING

NOT TO SCALE.



(29)

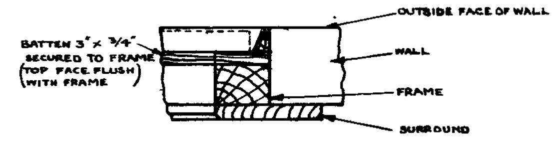
2 SETS OF INSULATORS MOUNTED HORIZONTAL (FOR OTHER DETAILS SEE (28))



3 SETS OF INSULATORS MOUNTED HORIZONTAL (FOR OTHER DETAILS SEE (28))

NOT TO SCALE.

(30)



SECTION ON A-A

ISSUED BY
D. OF TELS.
(TELS. 3E)
AIR MINISTRY

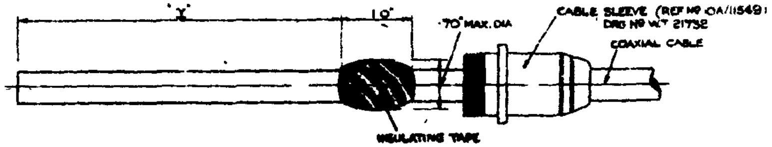
GROUND STATION EQUIPMENT INSTALLATION DETAILS

DRAWN	TRACED	CHECKED	APPROVED	DATE
HT	E.E.B	JGB 2-5-42	LMG SWH	2-5-42 3-5-42

DRG. No. WT 50105

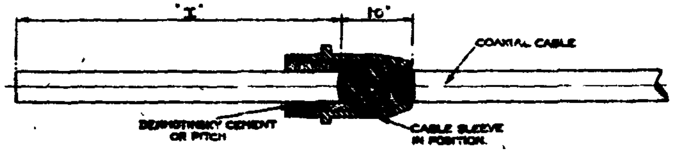
SHEET 4 OF 4 SHEETS

ISSUE NO. 1.
DATE 2-9-40
CHANGES

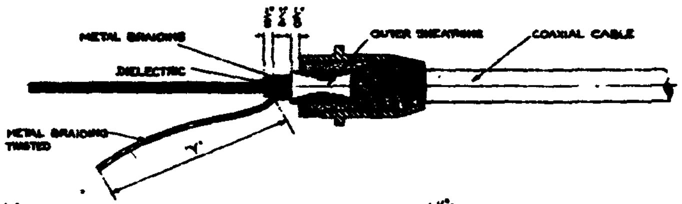


(a) PUT CABLE SLEEVE (REF. Nº 10A/11549) ON CABLE AS SHOWN

(b) LEAVING SUFFICIENT LENGTH ('X') OF CABLE TO REACH DESIRED POINT OF CONNECTION. BIND OVER OUTER SHEATING WITH INSULATING TAPE TO DIMENSION SHOWN ·70" MAX. DIA x 1·0" LONG.



(c) PULL CABLE SLEEVE REF. Nº 10A/11549 FIRMLY OVER INSULATING TAPE AND FILL IN REMAINDER OF CABLE SLEEVE WITH DEKHOTINSKY CEMENT (OBTAINABLE FROM MESSRS STANDARD TELEPHONES & CABLES) OR PITCH.

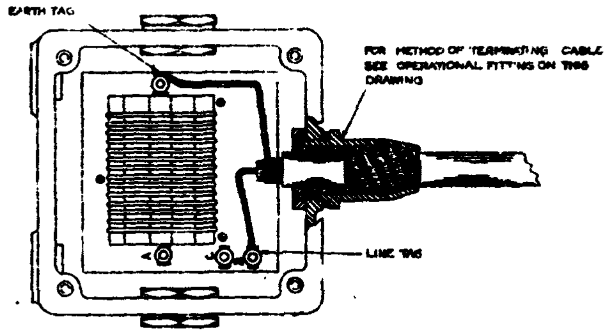


(d) OUTER CABLE SHEATHING TO BE CUT OFF TO DIMENSION (1/8"). WHEN CUTTING OUTER SHEATHING, CARE TO BE TAKEN NOT TO DAMAGE METAL BRAIDING.

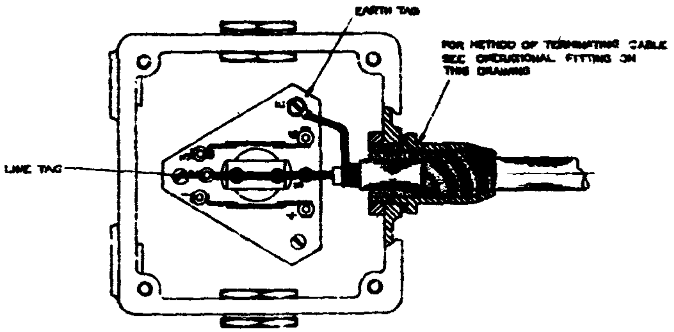
(e) METAL BRAIDING TO BE CUT BACK, LEAVING SUFFICIENT LENGTH (Y) TO REACH NEAREST EARTH POINT FOR BONDING PURPOSES, METAL BRAIDING TO BE UNWOVEN AND TWISTED TOGETHER AND TINNED TO FORM A CONDUCTOR

(f) DIELECTRIC OF CABLE CUT BACK TO DIMENSION SHEWN (1/8") AND CONDUCTOR TINNED FOR SOLDERING, WHEN CUTTING DIELECTRIC, CARE TO BE TAKEN NOT TO DAMAGE CONDUCTOR.

OPERATIONS FOR FITTING FLEXIBLE.
COAXIAL CABLE ·INTO CABLE SLEEVE.



TYPICAL INSTALLATION OF FLEXIBLE CABLE INTO
TYPE 2 MATCHING UNIT.



TYPICAL INSTALLATION OF FLEXIBLE CABLE
INTO TYPE .3. MATCHING UNIT.

USED ON
W/T. GROUND STATIONS.

ISSUE Nº
ALTER. Nº

TITLE:- TERMINATION OF FLEXIBLE COAXIAL CABLES IN MATCHING UNITS & JUNCTION BOXES.

ISSUED BY DRAWING OFFICE DIRECTORATE OF COMMUNICATIONS DEVELOPMENT.
MINISTRY OF
AIRCRAFT PRODUCTION

DRAWN	TRACED	CHECKED	DATE	APPROVED	DATE
			6/9/40		

DRG. Nº W.T. 23852.

ITEM Nº	DESCRIPTION	QTY	DRAWING Nº	REF. Nº	REMARKS
1	INSULATOR TYPE 9	7	W.T 10420	10B/1275	△
2	INSULATOR TYPE 68	20	W.T 22550	10B/156	△
3	WIRE COPPER HARD DRAWN	AS REQD.		5E/1775	△ 100 lb/MILE.
4	CORDAGE MANILA 1½" CIRC.	AS REQD		32A/50	△
5	CORDAGE MANILA 1" CIRC	AS REQD		32A/48	△
6					

△ D. of E SUPPLY

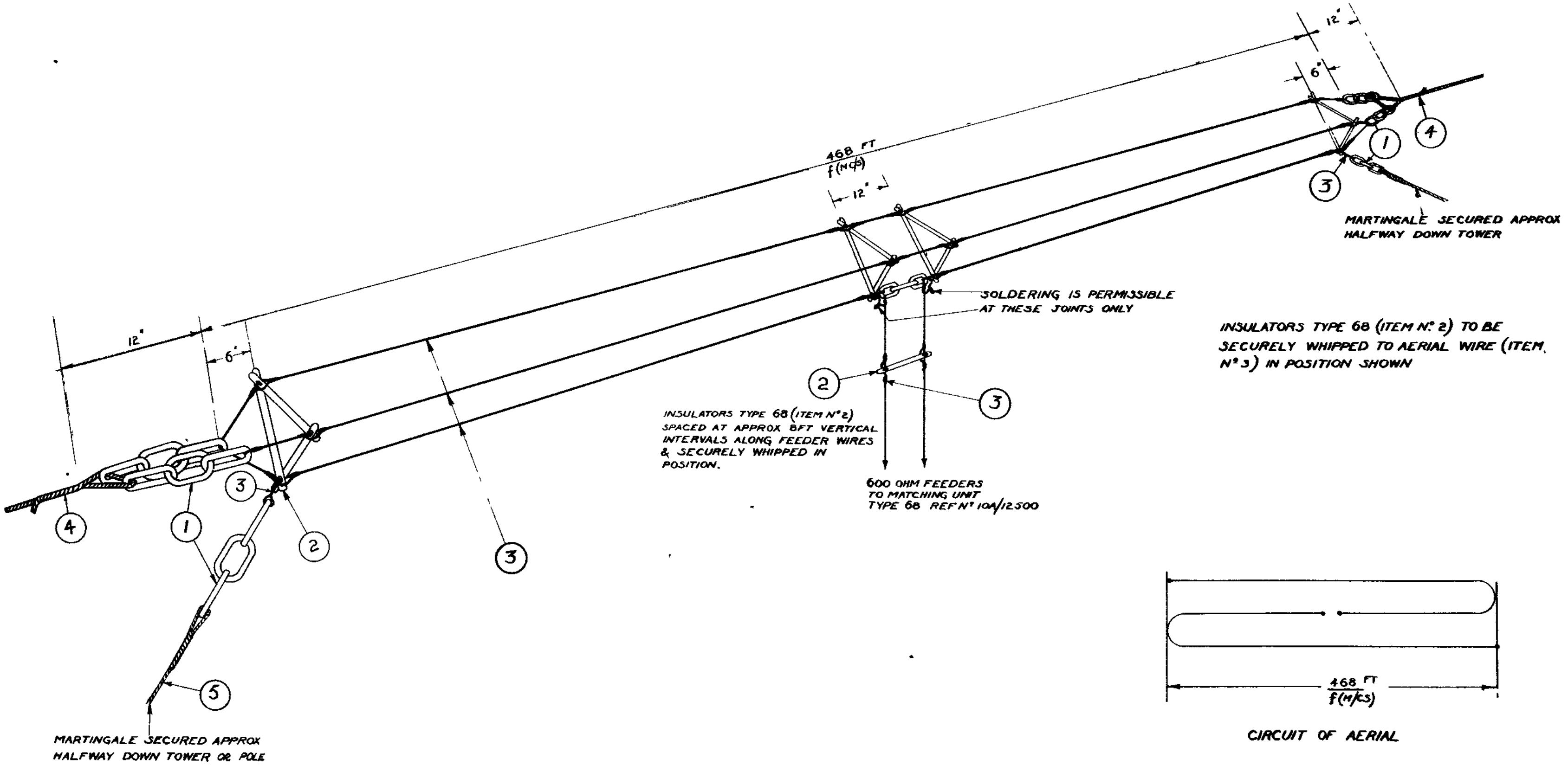
ISSUE Nº 1

DATE:-

CHANGES

NOTE:-

THIS AERIAL HAS A BROAD FREQUENCY RESPONSE CHARACTERISTIC AND WILL RECEIVE REASONABLY WELL FREQUENCIES DIFFERING GREATLY FROM THE OPTIMUM. FOR BEST RESULTS IT SHOULD BE ERECTED HALF A WAVELENGTH ABOVE GROUND



INSULATORS TYPE 68 (ITEM Nº 2) TO BE SECURELY WHIPPED TO AERIAL WIRE (ITEM Nº 3) IN POSITION SHOWN

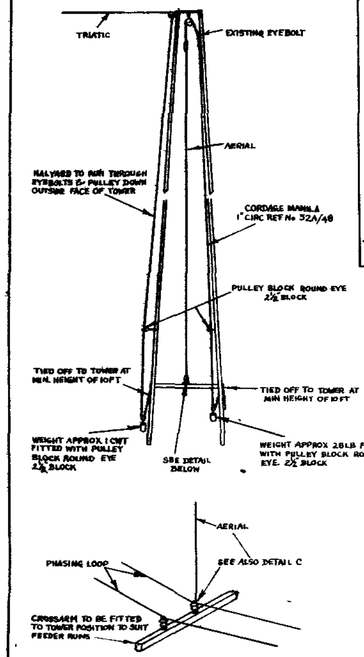
CIRCUIT OF AERIAL

AERIAL DIPOLE $\lambda/2$ 3 WIRE RECEIVING STATIONS

ISSUED BY **DIRECTORATE COMMUNICATIONS DEVELOPMENT R.D.C.3. . M.A.P.**

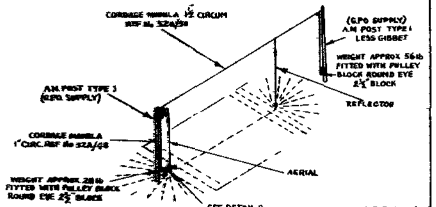
DRAWN	TRACED	CHECKED	APPROVED	DATE
JFG	SH	✓		6.1.42

DRG. Nº W.T. 50346



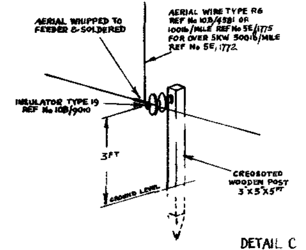
DETAIL B

METHOD OF RIGGING AERIAL IN TOWER & METHOD OF WEIGHTING TRIATIC. OTHER DETAILS AS ON MAIN DRAWING

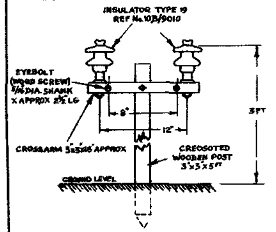


DETAIL A

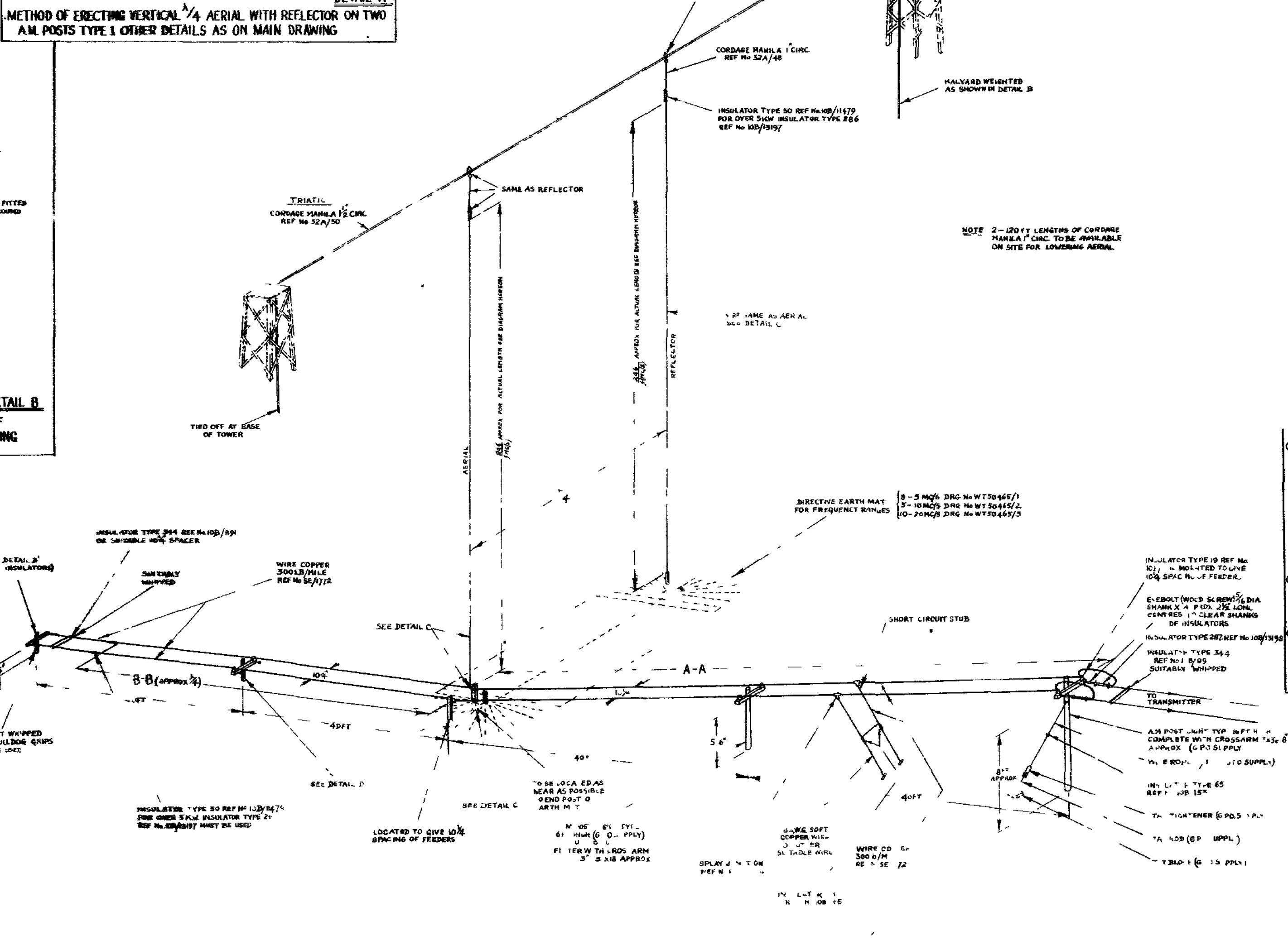
METHOD OF ERECTING VERTICAL λ/4 AERIAL WITH REFLECTOR ON TWO A.M. POSTS TYPE 1 OTHER DETAILS AS ON MAIN DRAWING

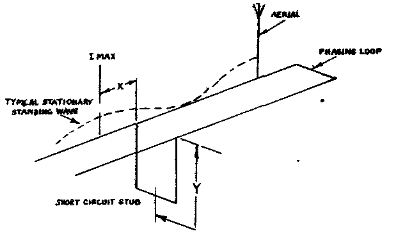


DETAIL C



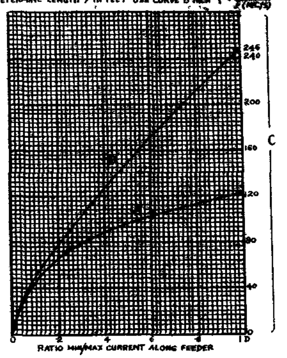
DETAIL D





TO DETERMINE LENGTH X IN FEET USE CURVE A THEN $X = \frac{C}{f(MC/S)}$

TO DETERMINE LENGTH Y IN FEET USE CURVE B THEN $Y = \frac{C}{f(MC/S)}$



CURVE FOR DETERMINING LENGTH & POSITION OF SHORT CIRCUIT STUB

MATCHING PROCEDURE

① WITH TRANSMITTER ON LOW POWER & USING STANDING WAVE METER WT 50495 DETERMINE CURRENT ALONG SECTION A-A (SEE MAIN DRG) AS FOLLOWS

(a) COMMENCING AT AERIAL, MOVE METER ALONG FEEDER LEG TO WHICH AERIAL IS ATTACHED, IN THE DIRECTION OF THE TRANSMITTER UNTIL MAX CURRENT (I MAX) POSITION IS REACHED, REPEAT ON OTHER LEG ADJUSTING LENGTH OF B-B (SEE MAIN DRG) UNTIL I MAX POINTS ARE OPPOSITE (SEE NOTE b) MARK THESE POINTS NOTING I MAX VALUE

(b) TO BRING I MAX POINTS OPPOSITE ALONG FEEDER LEGS, LENGTH B-B (SEE MAIN DRG) SHOULD BE SHORTENED OR INCREASED BY HALF THE DISTANCE BETWEEN THE TWO I MAX POINTS i.e. INCREASED IF THE SECOND READING IS NEARER THE TRANSMITTER THAN THE FIRST AND VICE VERSA

HAVING FOUND POSITION OF I MAX SLIDE METER ALONG EITHER LEG OF FEEDER DETERMINE VALUE OF I MIN

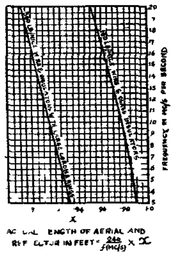
② TO DETERMINE VALUE OF X & Y (DIAGRAM ABOVE)

(a) OBTAIN RATIO OF I MIN/I MAX

(b) USING RATIO OBTAINED IN (a) DETERMINE CONSTANTS C FROM GRAPH ABOVE

(c) INSERT CONSTANTS IN FORMULÆ ABOVE GRAPH

③ USING OBTAINED VALUES OF X & Y CONSTRUCT & LOCATE STUB AS INDICATED IN DIAGRAM ABOVE



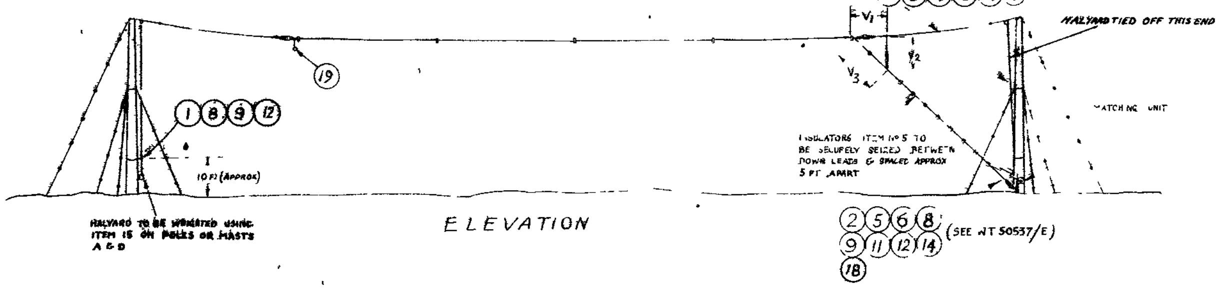
ACTUAL LENGTH OF AERIAL AND REFLECTOR IN FEET = $\frac{246}{f(MC/S)} \times X$

CHANGES
DATE 26 11·42
ISSUE No. 1
ISSUED BY D OF T TELS 3E AIR MINISTRY

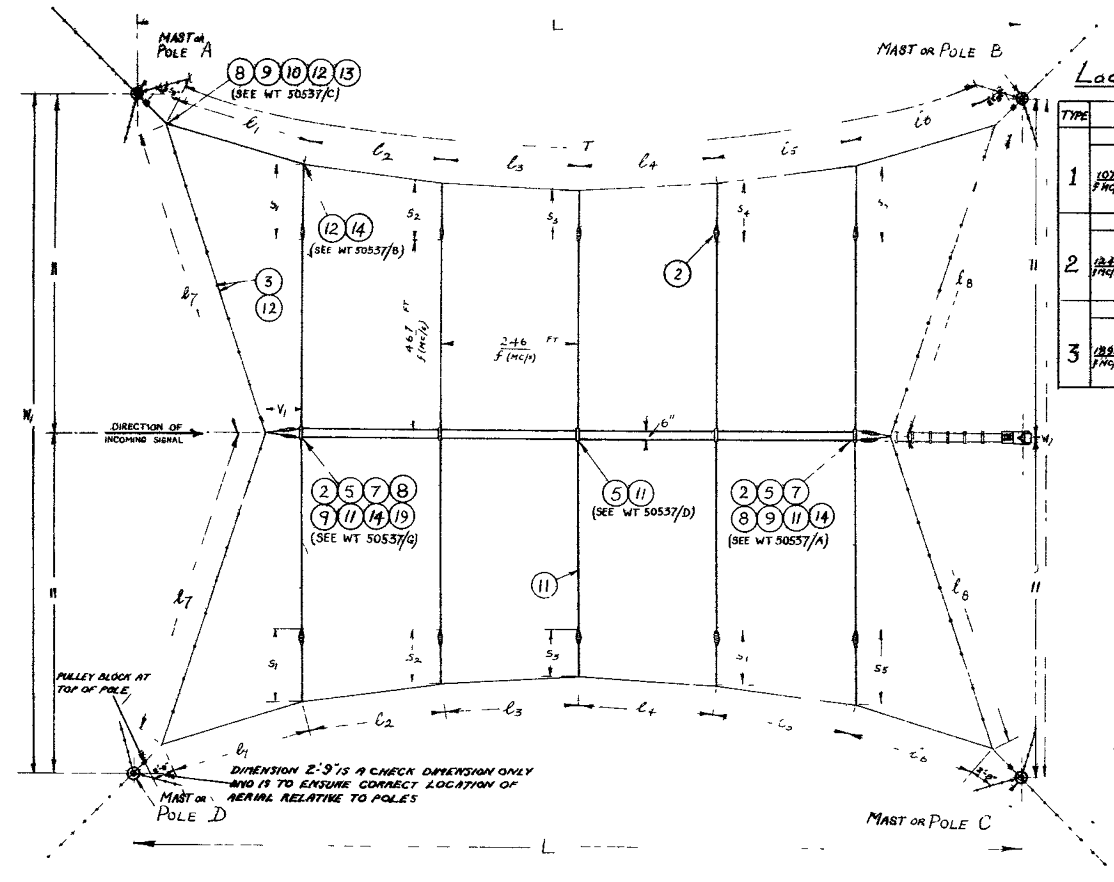
TYPICAL INSTALLATION & MATCHING DETAILS OF VERTICAL λ/4 AERIAL WITH REFLECTOR

DRAWN	TRACED	CHECKED	APPROVED	DATE
	K			26·11·42

DRG. No. WT 50477



ELEVATION



PLAN

ITEM No	DESCRIPTION	QTY	DRAWING No	REF No	REMARKS
1	BLOCK G.P SINGLE	3		4L/537	
2	INSULATOR TYPE 13	18	WT 14521	10B/7452	
3	INSULATOR TYPE 46	AS REQD		10B/6	
4					
5	INSULATOR TYPE 375	18		10B/1194	INSULATOR TYPE 56 REF No 10B/156 MAY BE USED
6	LIGHTNING ARRESTOR TYPE D	2		10B/72	
7	SAIL THIMBLE 1¾" DIA	2			CAT No 1160 OBTAINABLE FROM DAVEY & CO (LONDON) LTD
8	SHACKLE BOW HARP SHAPE ⅜ DIA	10			CAT No 1221
9	THIMBLE NON-CORRODIBLE STEEL	15		28c/6070	
10	THIMBLE NON CORRODIBLE STEEL	16		28c/6072	
11	WIRE COPPER HD	AS REQD		5E/1775	100 lb/MILE
12	WIRE ROPE FLEXIBLE ⅝" CIRCUM	AS REQD		29/2070	
13	WIRE ROPE FLEXIBLE ¾" CIRCUM	AS REQD		29/2071	
14	WIRE STEEL GALVANIZED 18 SWG	AS REQD		28c/3470	
15	WEIGHT (SEE TABLE FOR VALUE)	4			
16	SHACKLE BOW HARP SHAPE ⅝" DIA	4			CAT N° 1221 OBTAINABLE FROM DAVEY & CO (LONDON) LTD
17					
18	MOUNTING TYPE 32	1		10A/11999	
19	TERMINATING RESISTANCE 600Ω	1		WEST DRAYTON 10C/NIV 241	
20					

LOCATION OF POLES OR MASTS & RIGGING DIMENSIONS FOR STANDARD FISHBONE AERIALS

TYPE	L	W_1 & W_2	l_1 & l_6	l_2 & l_5	l_3 & l_4	l_7 & l_8	V_1 & V_2	V_3	S_1 & S_5	S_2 & S_4	S_3	T	BALANCE WEIGHT
	AERIAL SUSPENDED ON 4 AM POSTS TYPE 1 HAVING TOP BACKSTAYS & 3-STAYS IMMEDIATELY ABOVE SPLICE												
1	$\frac{1072}{f\,Mc/s}$ +10'5"	$\frac{1023}{f\,Mc/s}$ +11'4"	$\frac{44.8}{f\,Mc/s}$ +2'2"	$\frac{249}{f\,Mc/s}$	$\frac{246}{f\,Mc/s}$	$\frac{513}{f\,Mc/s}$ +2'8"	2'-0"	3'-0"	$\frac{37.6}{f\,Mc/s}$ +2'-0"	$\frac{9.4}{f\,Mc/s}$ +2'-0"	2'-0"	$\frac{1079\frac{1}{2}}{f\,Mc/s}$ +4'-4"	5 CWT
	AERIAL SUSPENDED ON 4 AM. POSTS TYPE 1 HAVING TOP BACKSTAYS ONLY												
2	$\frac{1240}{f\,Mc/s}$ +8'-4"	$\frac{1198}{f\,Mc/s}$ +12'7"	$\frac{138}{f\,Mc/s}$ +2'-11"	$\frac{253}{f\,Mc/s}$	$\frac{247}{f\,Mc/s}$	$\frac{622}{f\,Mc/s}$ +3'-5"	2'0"	3'-0"	$\frac{40}{f\,Mc/s}$ +2'-0"	$\frac{20}{f\,Mc/s}$ +2'0"	2'-0"	$\frac{1276}{f\,Mc/s}$ +5'-16"	2¾ CWT
	AERIAL SUSPENDED ON 4 - 70' STEEL MASTS HAVING TOP BACKSTAY ONLY												
3	$\frac{1391}{f\,Mc/s}$ +15'1"	$\frac{1359}{f\,Mc/s}$ +16'-11"	$\frac{555}{f\,Mc/s}$ +5'-7"	$\frac{267}{f\,Mc/s}$	$\frac{248}{f\,Mc/s}$	$\frac{1032}{f\,Mc/s}$ +6'-1"	2'0"	3'-0"	$\frac{139}{f\,Mc/s}$ +2'-0"	$\frac{35}{f\,Mc/s}$ +2'-0"	2'-0"	$\frac{2140}{f\,Mc/s}$ +11'-2"	1¾ CWT

$\frac{CONSTANT}{f\,Mc/s}$ = ----FT ie (ON A FREQUENCY OF 10 Mc/s $l_3 = \frac{248}{10} = 24.8$ FT)

NOTE –

DIMENSIONS 2'-9" ARE FOR LOCATION PURPOSES ONLY. THESE DIMENSIONS TO BE INCREASED BY 1'-6" WHERE 70 FT STEEL MASTS ARE USED & BLOCKS. G.P. SINGLE & STROPS ARE NOT REQUIRED.

FOR STANDARD RIGGING DETAILS SEE DRG N° WT 50537.

FOR RIGGING DIMENSIONS OF AERIALS FOR PARTICULAR STATIONS SEE DRG N° WT 50567

FOR POLE STAYING DETAILS SEE DRG N° WT 50555

CHANGES
DATE –
ISSUE No 1
ISSUED BY
D OF TELS
A M

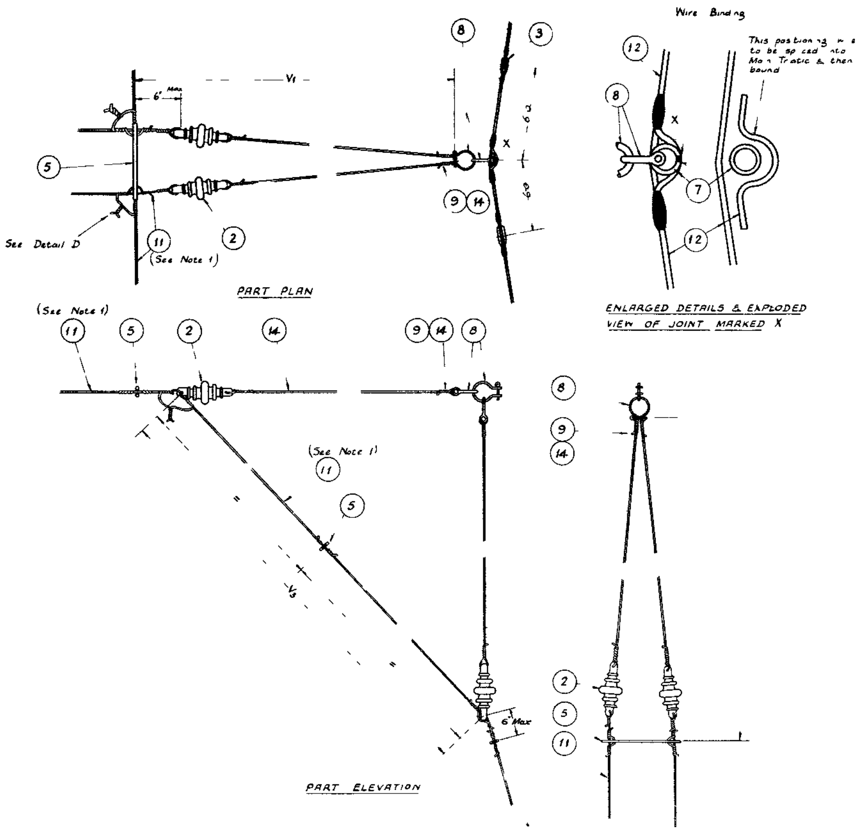
NOT TO SCALE

AERIAL. FISHBONE 10 ELEMENT. (SUSPENDED BETWEEN 4 POLES) G.A.

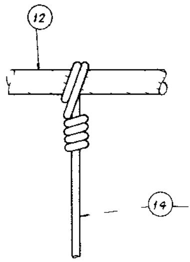
DRAWN	TRACED	CHECKED	APPROVED	DATE
J F G		J.C.B.		27·11·42

DRG No WT 50554

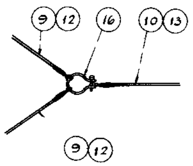
ISSUE No 1	
DATE 25-11-42	
CHANGES	



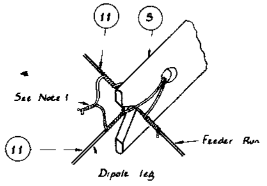
DETAIL A



DETAIL B

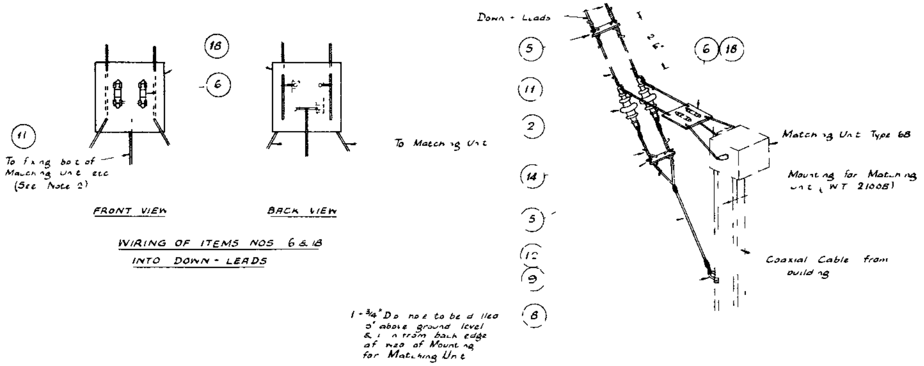


DETAIL C



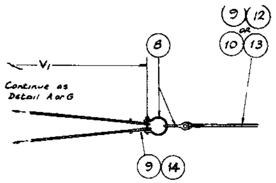
METHOD OF JOINING DIPOLE LEG TO AERIAL FEEDER RUN

DETAIL D

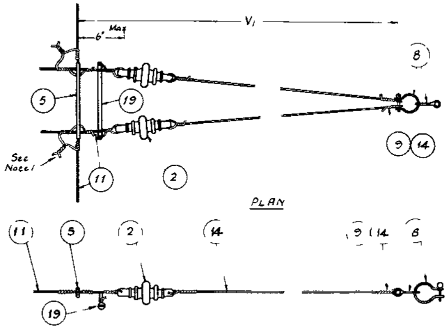


WIRING OF ITEMS NOS 6 & 18 INTO DOWN - LEADS

DETAIL E



DETAIL F



DETAIL G

NOTES

1 WIRE ITEM No 11 TO BE SECURELY WHIPPED TO INSULATORS TO TAKE FULL MECHANICAL STRAIN & THEN ELECTRICAL CONNECTION TO BE MADE & SOLDERED

2 FOR EARTHING LIGHTNING ARRESTOR & MATCHING UNIT CONNECT LIGHTNING ARRESTOR ITEM No 6 TO FIXING BOLT OF MATCHING UNIT USING WIRE, ITEM No 11
CONNECT 20 FT OF WIRE ITEM No 11 TO FIXING BOLT OF MATCHING UNIT & THEN BURY IN GROUND ALONG COAXIAL CABLE TRENCH

FOR G A & QUANTITIES OF MATERIALS SEE THE FOLLOWING DRAWINGS –

10 ELEMENT SUSPENDED ON 4 POLES OR MASTS WT 50554
10 ELEMENT SUSPENDED ON 6 POLES OR MASTS WT 50570
12 ELEMENT SUSPENDED ON 4 POLES OR MASTS WT 50560
2 ELEMENT SUSPENDED ON 6 POLES OR MASTS WT 50550

NOT TO SCALE

ITEM No	DESCRIPTION	DRAWING No	REF No	REMARKS
1	BLOCK G P SINGLE		4L/537	
2	INSULATOR TYPE 13	WT 14521	108/7652	
3	INSULATOR TYPE 46		108/6	
4				
5	INSULATOR TYPE 375		108/1194	INSULATOR TYPE 68 REF No 108/56 MAY BE USED
6	LIGHTNING ARRESTOR TYPE D		108/72	
7	SAIL THIMBLE 1¾" DIA			CAT No 1160 OBTAINABLE FROM DAVEY Co (LONDON) LTD
8	SHACKLE BOW HARP SHAPE ¾" DIA			CAT No 1221 OBTAINABLE FROM DAVEY Co (LONDON) LTD
9	THIMBLE NON-CORRODIBLE STEEL			FOR SIZE & REF No SEE G A
10	THIMBLE NON-CORRODIBLE STEEL		28C/6072	
11	WIRE COPPER H/D		5E/1775	100 LB / MILE
12	WIRE ROPE FLEXIBLE 1⅝" CIRCUM			FOR CIRCUM OF ROPE SEE G A
13	WIRE ROPE FLEXIBLE ¾" CIRCUM		29/2071	
14	WIRE STEEL GALVANIZED 18 SWG		28C/3470	
15	WEIGHT			FOR VALUE SEE G A
16	SHACKLE BOW HARP SHAPE ⅝" DIA			CAT No 1221 OBTAINABLE FROM DAVEY Co (LONDON) LTD
17				
18	MOUNTING TYPE 32		10A/11999	
19	TERMINATING RESISTANCE		West Drayton 10C/KV 241	600 Ω
20				
21				
22				

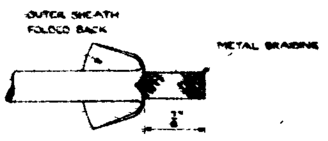
ISSUED BY
D OF TELS
AIR MINISTRY

AERIAL. FISHBONE. RIGGING DETAILS. STANDARD.

DRAWN	TRACED	CHECKED	APPROVED	DATE
JFG	IG			

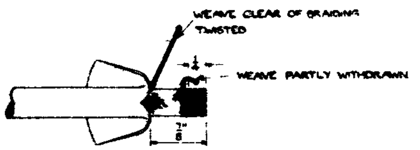
DRG. No. WT 50537.

ISSUE NO 1.
DATE 5-10-40
CHANGES



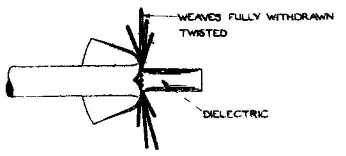
OUTER SHEATH TO BE SLIT TO DIMENSION SHOWN ($\frac{7}{8}$") AND FOLDED BACK OVER METAL BRAIDING, CARE TO BE TAKEN NOT TO DAMAGE METAL BRAIDING WHEN CUTTING OUTER SHEATH

FIG. 1



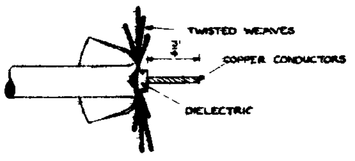
UNWEAVE METAL BRAIDING TO DIMENSION SHOWN ($\frac{7}{8}$")
METHOD FOR UNWEAVING - COMMENCING APPROXIMATELY $\frac{1}{4}$" BACK FROM CUT END OF BRAIDING, PICK UP, WITH ANY SUITABLE POINTED INSTRUMENT, ONE INDIVIDUAL WEAVE (6/ 0076" TINNED COPPER WIRE) THE SELECTED WEAVE TO BE THEN PULLED OUT CLEAR OF BRAIDING REPEAT THIS OPERATION UNTIL SELECTED WEAVE (6/ 0076 TINNED COPPER WIRE) IS CLEAR OF REST OF BRAIDING AS SHOWN
TWIST THE INDIVIDUAL STRANDS OF WEAVE (6/ 0076" TINNED COPPER WIRE)

FIG. 2



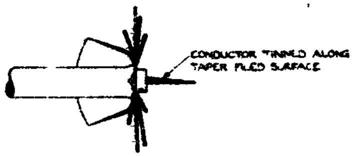
REMANDER OF WEAVES (6/ 0076" TINNED COPPER WIRE) TO BE SIMILARLY TREATED IN TURN, UNTIL REQUIRED LENGTH OF BRAIDING HAS BEEN UNWOVEN
NOTE :- SPECIAL CARE SHOULD BE TAKEN TO PREVENT BREAKAGE OF STRANDS DURING THE ABOVE OPERATIONS AND A SHARP TOOL SHOULD NOT BE USED

FIG 3



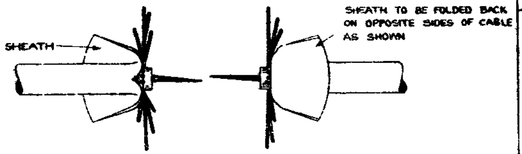
DIELECTRIC TO BE CUT BACK TO DIMENSION SHOWN ($\frac{3}{4}$") CARE BEING TAKEN NOT TO DAMAGE THE COPPER CONDUCTORS WHEN CUTTING DIELECTRIC

FIG. 4



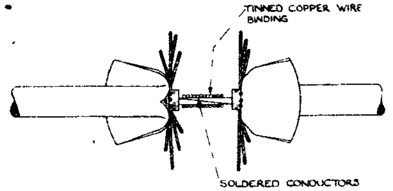
TIN EXPOSED LENGTH OF COPPER CONDUCTOR AND FILE DOWN AS SHOWN, AFTERWARDS TIN ALONG FILED SURFACE

FIG. 5



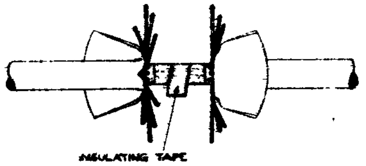
OPERATIONS DESCRIBED ABOVE ARE TO BE NOW CARRIED OUT ON THE OTHER END OF CABLE TO FORM THE COMPLETE JOINT NOTE - WHEN JOINT IS MADE THE TWO OUTER SHEATHS SHOULD BE FOLDED BACK OPPOSITE EACH OTHER AS SHOWN

FIG 6



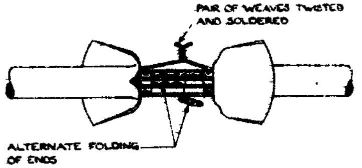
LAY THE TWO CONDUCTORS TOGETHER AS SHOWN AND BIND WITH TINNED COPPER WIRE APPROXIMATELY No 24 S W G (022) AND SOLDER SECURELY
NO FLUX OTHER THAN RESIN (OR METHYLATED SPIRIT AND RESIN MIXTURE) TO BE USED WHEN MAKING SOLDERED CONNECTIONS

FIG 7



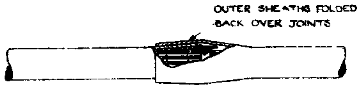
THE SOLDERED JOINT IS TO BE BOUND WITH INSULATING TAPE TO THE ORIGINAL DIAMETER OF THE EXISTING DIELECTRIC

FIG. 8



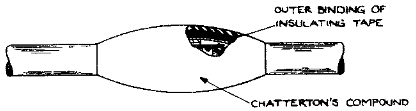
IT IS NOW REQUIRED TO JOIN THE TWO SETS OF TWISTED WEAVES TOGETHER, TO FORM A CONTINUOUS BRAID ACROSS THE JOINT. THIS IS FACILITATED BY TAKING TWO OPPOSITE WEAVES, TWISTING TOGETHER AND SOLDERING.
EACH PAIR OF CORRESPONDING WEAVES TO BE TAKEN AND SIMILARLY TREATED, SO THAT ON COMPLETION OF THE LAST PAIR, A CONTINUOUS BRAID WILL BE FORMED ACROSS THE JOINT THE ENDS TO BE ALTERNATELY FOLDED BACK OVER THE JOINT AS SHOWN, TO INCREASE THE SCREENING EFFECT

FIG 9



THE OUTER SHEATHS TO BE FOLDED BACK AND PRESSED NEATLY OVER JOINT, CARE BEING TAKEN NOT TO DISARRANGE THE TWISTED WEAVES

FIG. 10



THE WHOLE TO BE BOUND WITH INSULATING TAPE AND SEALED OFF WITH CHATTERTON'S COMPOUND TO MAKE A THOROUGHLY WATERPROOF JOINT

FIG 11

USED ON
W T GROUND STATIONS

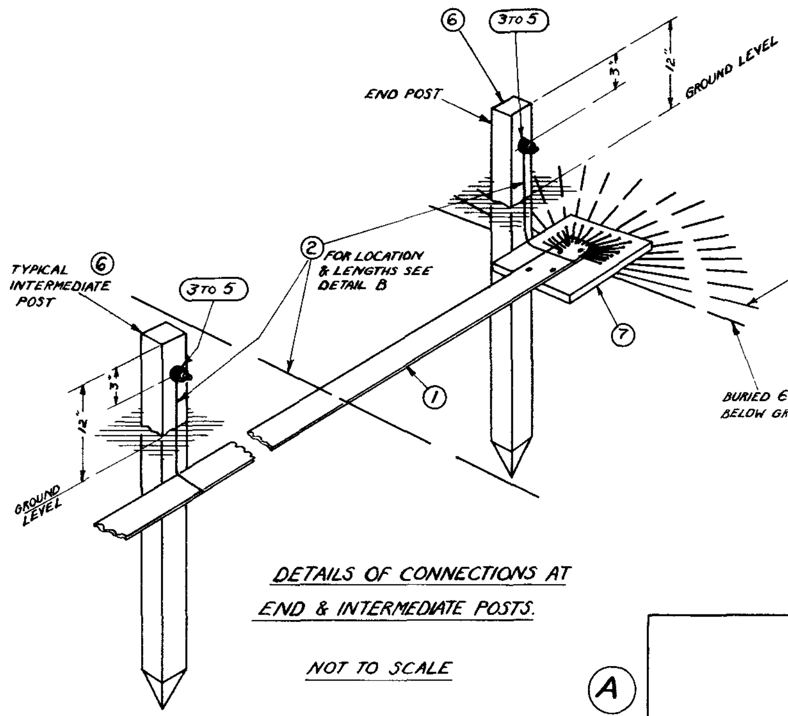
ISSUE NO
ALTER. NO

TITLE:- TYPICAL JOINTING OF COAXIAL CABLES.

ISSUED BY DRAWING OFFICE DIRECTORATE OF COMMUNICATIONS DEVELOPMENT.
MINISTRY OF AIRCRAFT PRODUCTION

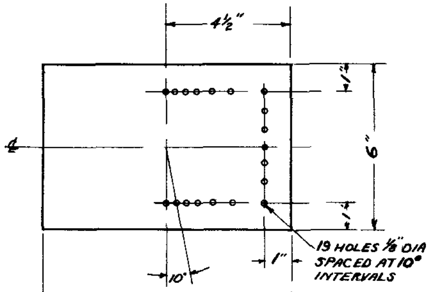
DRAWN	TRACED	CHECKED	DATE	APPROVED	DATE
	H W 10-10 40		14/10/40		

DRG. No W.T. 24011



DETAILS OF CONNECTIONS AT END & INTERMEDIATE POSTS.

NOT TO SCALE



BLOCK WOODEN ½" THICK

DETAILS OF DRILLINGS

NOT TO SCALE

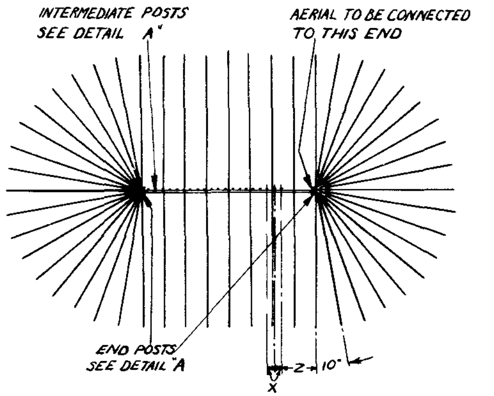
ITEM 7

ITEM Nº	DESCRIPTION	QUANTITY			REF Nº	REMARKS	
		PART 1	PART 2	PART 3			
1	COPPER STRIP 20 SWG X 2" WIDE	80 FT	50 FT	25 FT		#	
2	COPPER WIRE 14 SWG	1½ MILES	1000 YDS.	400 YDS	308/568	#	
3	BOLT ⅜" BSF X 3" BRASS	17	22	22		# 1 PER POST	OR NEAREST AVAILABLE SIZE
4	WASHERS ⅜" WHIT BRASS	60	70	70		# 3 PER POST	
5	LOCKNUTS ⅜" BSF BRASS	60	70	70		# 3 PER POST	
6	HARDWOOD POST 2"X2"X3FT	17	22	22		#	
7	HARWOOD BLOCK 9"X6"X½"	2	2	2		#	

D OF W SUPPLY & FIT

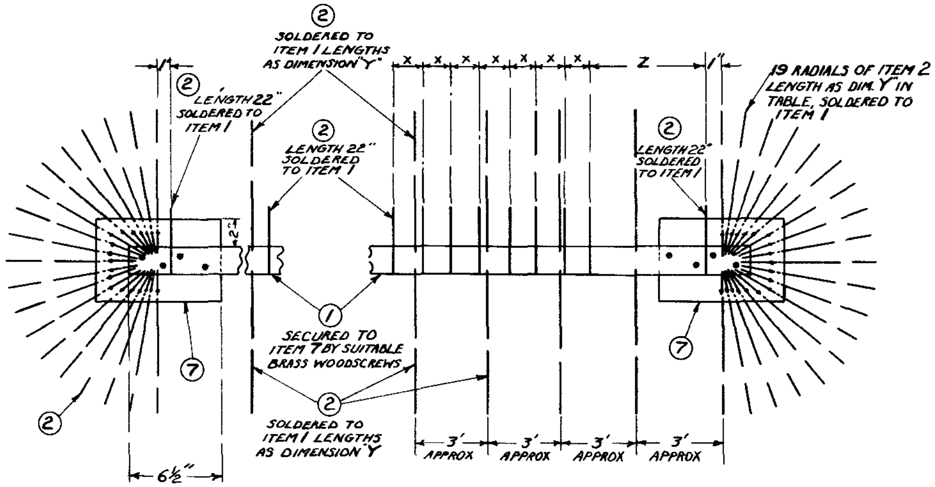
ALL WOODWORK TO BE PROTECTED AGAINST MOISTURE ETC

ALL JOINTS TO BE HARD SOLDERED & PROTECTED WITH 2 COATS OF BITUMINOUS PAINT OR BY OTHER SUITABLE MEANS



GENERAL ARRANGEMENT

NOT TO SCALE



NOT TO SCALE

LOCATIONS AND LENGTHS OF RADIAL WIRES

FOR ALL LETTERED DIMENSIONS & NUMBER OF STRIPS OF ITEM 2, SEE TABLE ON RIGHT

Ⓑ

TABLE OF DIMENSIONS ETC

PART Nº	FREQUENCY RANGE	DIMENSIONS IN FT.			Nº OF STRIPS OF ITEM 2 TO DIM Y	Nº OF 22" LENGTHS OF ITEM 2
		X	Y	Z		
1	3 TO 5 MCS	4	80	20	90	17
2	5 TO 10 MCS	2	40	10	68	22
3	10 TO 20 MCS	1	20	5	52	22

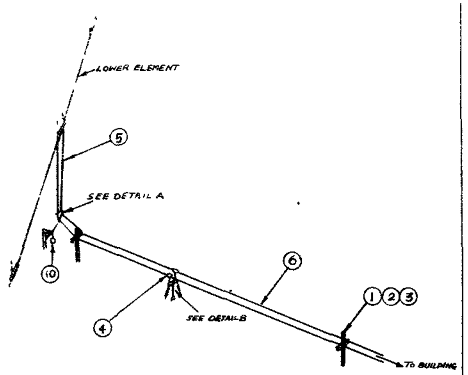
CHANGES
DATE 9.10 42
ISSUE 1

ISSUED BY
D OF TELS
AIR MINISTRY

EARTH SYSTEM FOR VERTICAL ¼ AERIALS WITH REFLECTOR RANGE 3-20 MCS.

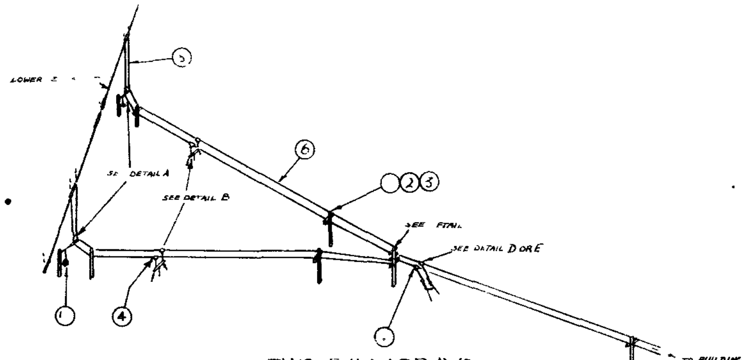
DRAWN	TRACED	CHECKED	APPROVED	DATE
HCAA	SH	JGB	S HOBDAY	9 10 42

DRG. Nº W.T. 50465.



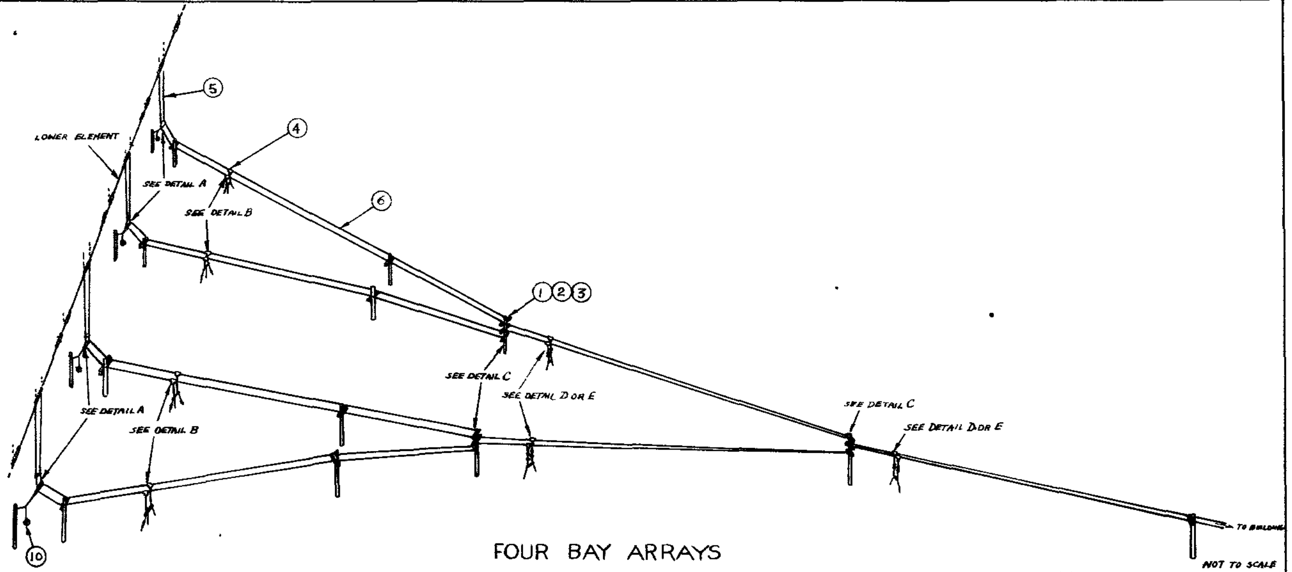
SINGLE BAY ARRAYS

NOT TO SCALE



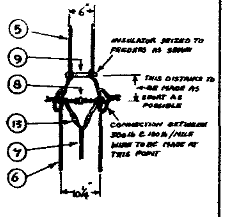
TWO BAY ARRAYS

NOT TO SCALE



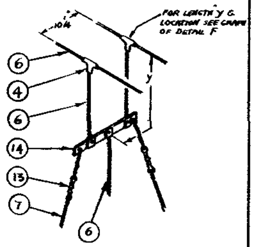
FOUR BAY ARRAYS

NOT TO SCALE

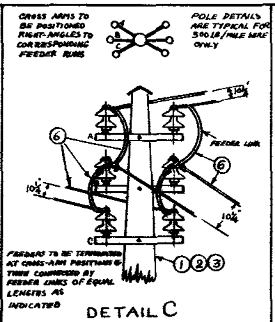


DETAIL A

NOT TO SCALE

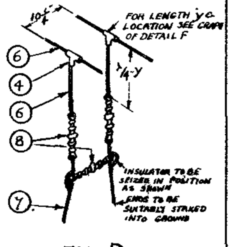


DETAIL B



DETAIL C

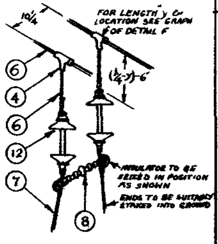
NOT TO SCALE



DETAIL D

POWER UP TO 5 KW

NOT TO SCALE



DETAIL E

POWER UP TO 25 KW

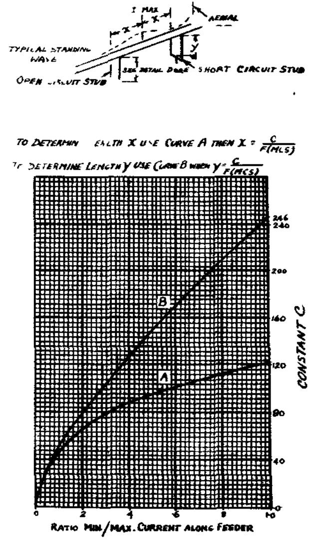
NOT TO SCALE

ITEM No	DESCRIPTION	DRAWING No	RE No	REF. SHEETS FOR INSTALLATION DETAILS	REMARKS
1	LIGH 16			50106 SHEE	
2	INSULATOR TY	WT 4090	108/9		
3	IMBER 5"				
4	SPLAY CT	WT 50125	2794		
5	WIRE ... D DRAW		E/1		00 lb/MILE
6	WIRE COPPER ... 4		5E/17		300 lb/MILE
7	CORDAGE ... CUM		32A/4		
8	INSULATOR T P 50	WT 2179	... 479		
9	INSULATOR TYP 575		108/194		INSULATOR TYPE ... MAY BE USED 108/...
10	WEIGH AERIA 4	WT 50664			
11					
12	INSULATOR ... TYPE 2	... No ...	108/1320		
13	INSULATOR TYPE 13	WT 14521	108/7652		
14	BAR SHORTING FOR ... Ω FEEDER LINES	WT 50438/A			

NOTE: ALL ITEMS INDICATED ABOVE ARE CALLED FOR ON AERIAL DRAWING OR INSTALLATION COMPLETE

THIS DRAWING IS BASED ON FEEDER LINES OF 300LB/MILE WIRE SPACED AT 10¼" CENTRES

WHERE 100LB/MILE WIRE FEEDERS SPACED AT 6" CENTRES ARE EMPLOYED THE FOLLOWING MODIFICATIONS SHOULD BE CARRIED OUT.—
DETAIL A USE ITEM No 13 INSTEAD OF ITEM No 8
DETAIL B AMEND ITEM No 14 TO READ WT 50438/B INSTEAD OF WT 50438/A
DETAIL D USE ITEM No 13 INSTEAD OF ITEM No 8 AS SPACING INSULATOR
DETAIL E USE ITEM No 13 INSTEAD OF ITEM No 8



TO DETERMINE LENGTH X USE CURVE A THEN $X = \frac{C}{F(MCS)}$

TO DETERMINE LENGTH Y USE CURVE B WHEN $Y = \frac{C}{F(MCS)}$

CURVE FOR DETERMINING LENGTHS & POSITIONS OF OPEN & SHORT CIRCUIT STUBS

DETAIL F

FOR LOCATION OF POLES SEE POLE LAYOUT OR I.C
FOR DETAILS OF ARRAYS SEE ARRAY DRAWING & WT 50250
FOR RIGGING DETAILS OF ARRAYS SEE WT 50190

CHANGES
DATE - 28.9.42
ISSUE No 1

ISSUED BY
DIRECTORATE OF TELECOMMUNICATIONS
(TELE 3E)
AM

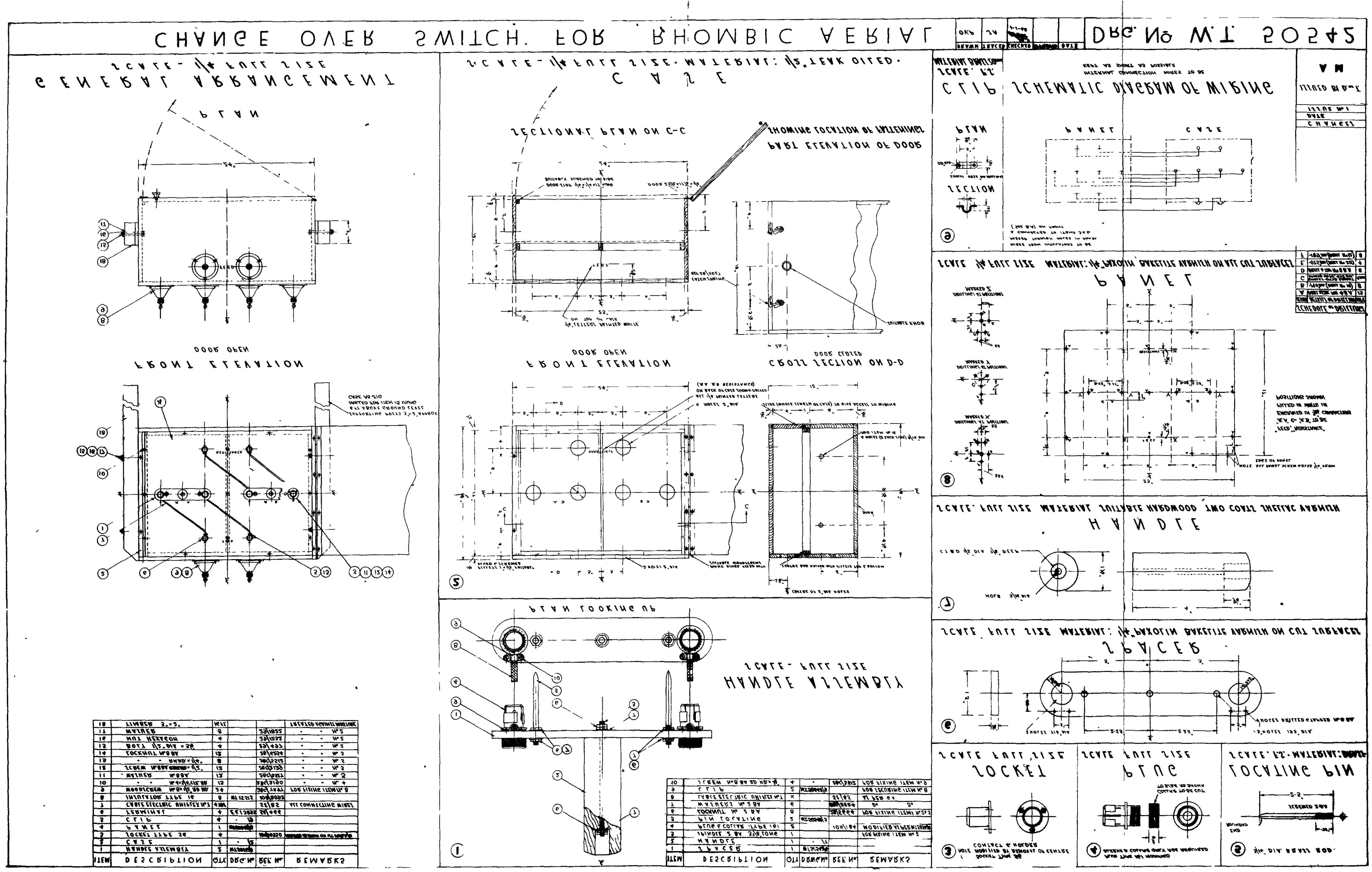
AERIAL ARRAYS. MATCHING DETAILS

DRAWN	TRACED	CHECKED	APPROVED	DATE
JFG	...	GHS	LMG	28.4.42
			SWH	27.4.42

DRG. No WT 50191

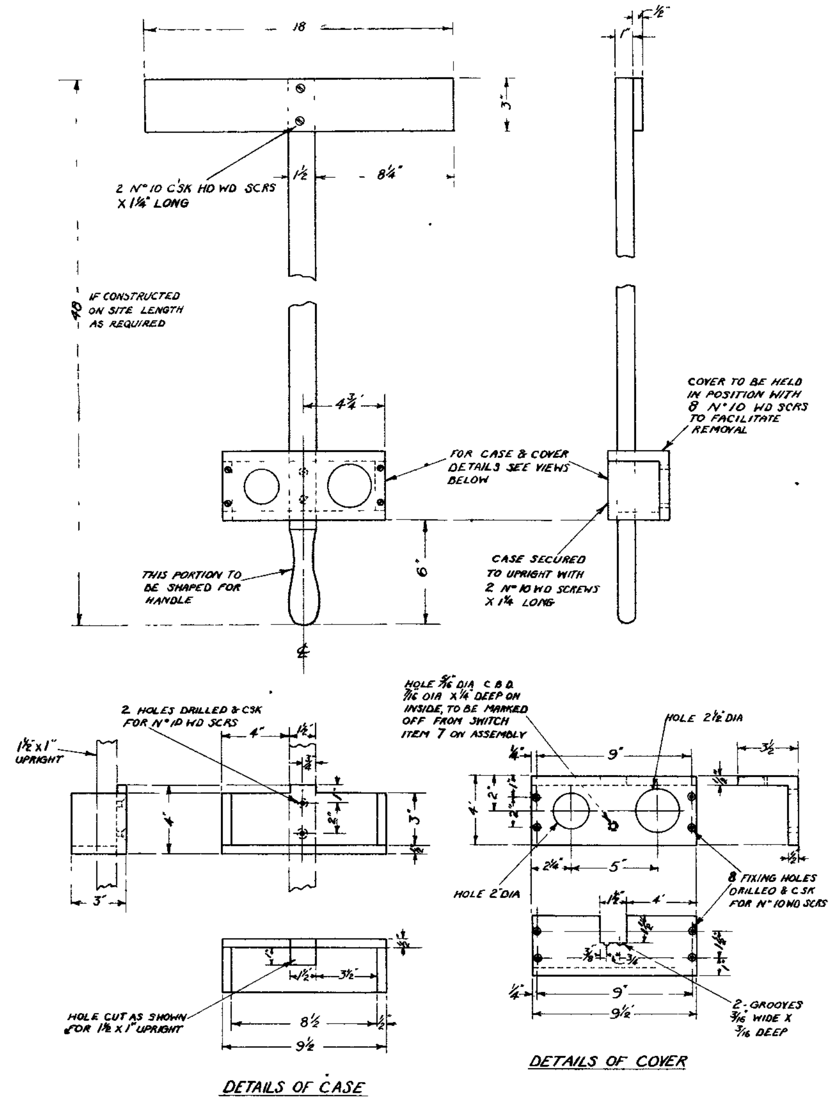
CHANGE OVER SWITCH FOR RHOMBIC AERIAL

DRG. No W.T. 50542



ITEM	DESCRIPTION	QTY	DRG. No	REF. No	REMARKS
18	TIMBER 3"×2"	16FT			TREATED AGAINST ROTTING
17	WASHER	8		[illegible]	" " No 2
16	NUT HEXAGON	4		[illegible]	" " No 2
15	BOLT 1/2" DIA × [illegible]	4		[illegible]	" " No 2
14	LOCKNUT No 2BA	12		[illegible]	" " No 3
13	" " RD HD × 1/4"	8		[illegible]	" " No 3
12	SCREW No 2BA [illegible] × 1/2"	12		[illegible]	" " No 3
11	WASHER No 2BA	12		[illegible]	" " No 3
10	" " No 4 × 3/4" CSK HD	12		[illegible]	" " No 4
9	WOODSCREW No 8 × [illegible] RD HD	24		[illegible]	FOR FIXING ITEM No 8
8	INSULATOR TYPE [illegible]	8	[illegible]	[illegible]	
7	CABLE ELECTRIC UNIFLEX No 1	[illegible]		[illegible]	ALL CONNECTING WIRES
6	TERMINAL	4	[illegible]	[illegible]	
5	CLIP	4	" [illegible]		
4	PANEL	1	[illegible]		
3	SOCKET TYPE [illegible]	4		[illegible]	[illegible]
2	CASE	1	" [illegible]		
1	HANDLE ASSEMBLY	2	[illegible]		

ITEM	DESCRIPTION	QTY	DRG. No	REF. No	REMARKS
10	SCREW No 6 BA RD HD × [illegible]	4	"	[illegible]	FOR FIXING ITEM No 9
9	CLIP	2	[illegible]		FOR SECURING ITEM No 8
8	CABLE ELECTRIC UNIFLEX No 1	X		[illegible]	AS PER GA
7	WASHERS No 2 BA	6		[illegible]	Do Do
6	LOCKNUT No 2 BA	8		[illegible]	FOR FIXING ITEMS No 2 & 5
5	PIN LOCATING	2	[illegible]		
4	PLUG & COLLAR TYPE [illegible]	2		[illegible]	MODIFIED AS PER [illegible]
3	SPINDLE 2 BA [illegible] LONG	1			FOR FIXING ITEM No 2
2	HANDLE	1	" [illegible]		
1	SPACER	1	[illegible]		

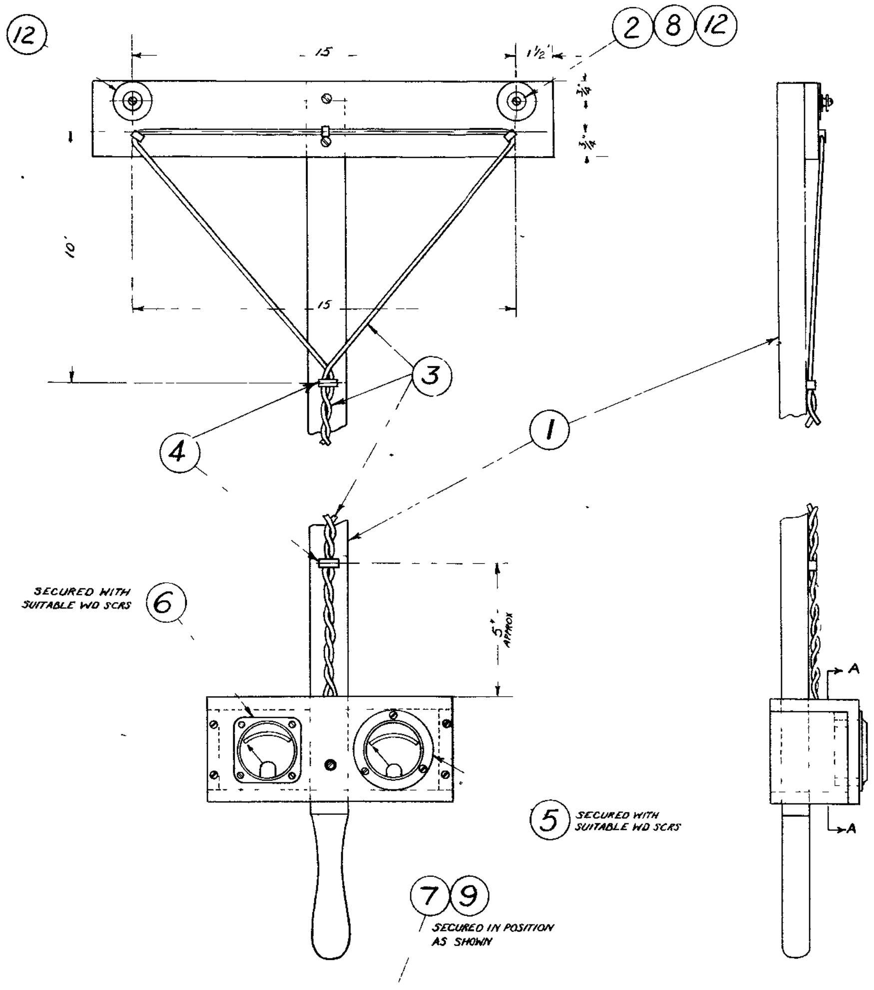


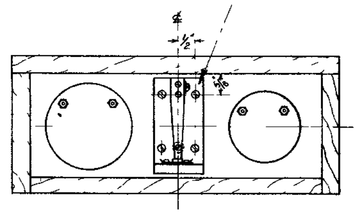
NOTE: ALL JOINTS TO BE SCREWED & GLUED

① FRAME

MATL - DEAL, P.A.D

SCALE ¼





SECTION A-A

SCALE - ½

GENERAL ARRANGEMENT.

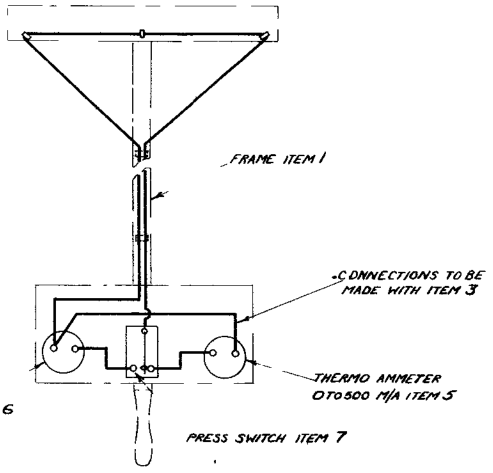
SCALE - ⅜ FULL SIZE

ITEM Nº	DESCRIPTION	Nº OFF	DRG Nº	REF Nº	REMARKS
1	FRAME	1	THIS DRAWING		
2	RUNNER	2			
3	CABLE ELECTRIC L.T. UNIFLEX 4	12 FT		5E/84	
4	CLEAT INSULATED STAPLE	6			
5	THERMO AMMETER 0-500 M/A	1		10A/9481	
6	THERMO AMMETER 0-120 M/A	1		10A/10981	
7	PRESS SWITCH	1	THIS DRG		SEE ITEMS 15 TO 27
8	WOODSCREW Nº 4 RD HD X ¾" LONG	2			
9	WOODSCREW Nº 4 RD HD X ½" LONG	4			
10	WOODSCREW Nº 10 CSK HD X 1¼" LONG	12			USED ON FRAME ITEM 1
11					
12	WASHER	2	THIS DRG		
13					
14					
	ITEMS FOR SWITCH G A ITEM 7				
15	BASE	1	THIS DRAWING		
16	MOUNTING CONTACT	1			
17	BLOCK MOUNTING	1			
18	SPRING CONTACT	1			
19	PLUNGER	1			
20	CONTACT	2			
21	LUG CONNECTION Nº 8 BA	2			
22	SCREW Nº 8BA CH HD X 3/16" LONG	4			BRASS NICKEL PLATED
23	SCREW Nº 8BA RD HD X 3/16" LONG	2			
24	SCREW Nº 8 BA C SK HD X ⅜ LONG	4			
25	SCREW Nº 6BA RD HD X ¼" LONG	1			
26	SCREW Nº 6BA RD HD X ⅜" LONG	1			
27	WASHER Nº 6BA STANDARD	1			

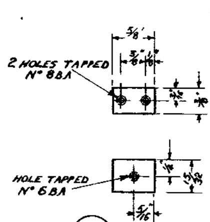
ISSUE 1

DATE 5-11-42

CHANGES



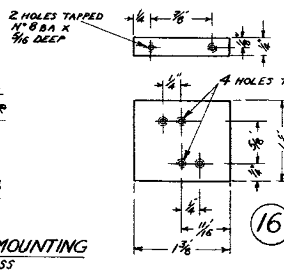
WIRING DIAGRAM



⑰ BLOCK MOUNTING

MATL BRASS

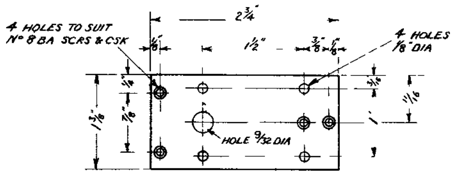
SCALE FULL SIZE



⑯ MOUNTING CONTACT

MAT PAXOLIN

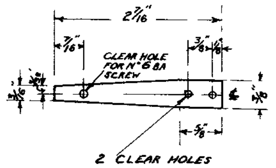
SCALE FULL SIZE



⑮ BASE

MAT ⅛ PAXOLIN

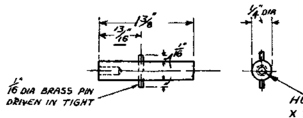
SCALE FULL SIZE



⑱ SPRING CONTACT

MATL - Nº 22 SWG PHOSPHOR BRONZE

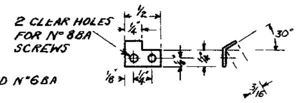
SCALE - FULL SIZE



⑲ PLUNGER

MATL EBONITE

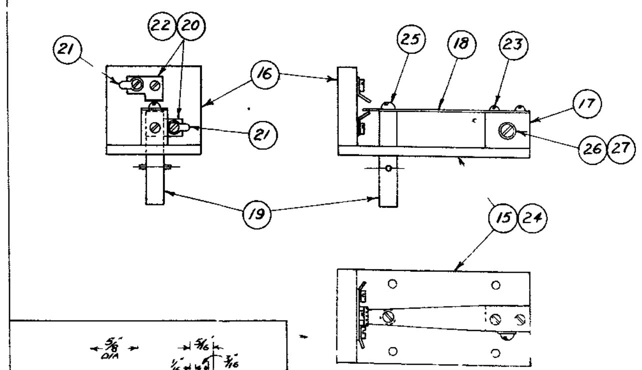
SCALE - FULL SIZE



⑳ CONTACT

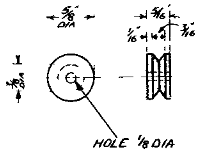
MATL Nº 20 SWG BRASS

SCALE FULL SIZE



⑦ PRESS SWITCH GENL ARRGT

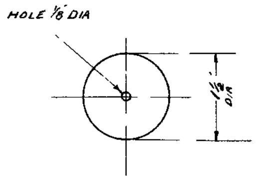
SCALE - FULL SIZE



② RUNNER

MATL BRASS

SCALE - FULL SIZE



THICKNESS Nº 18 SWG (·048")

⑫ WASHER

MATERIAL - BRASS

SCALE - FULL SIZE

ISSUED BY
D. OF TELS
AIR
MINISTRY

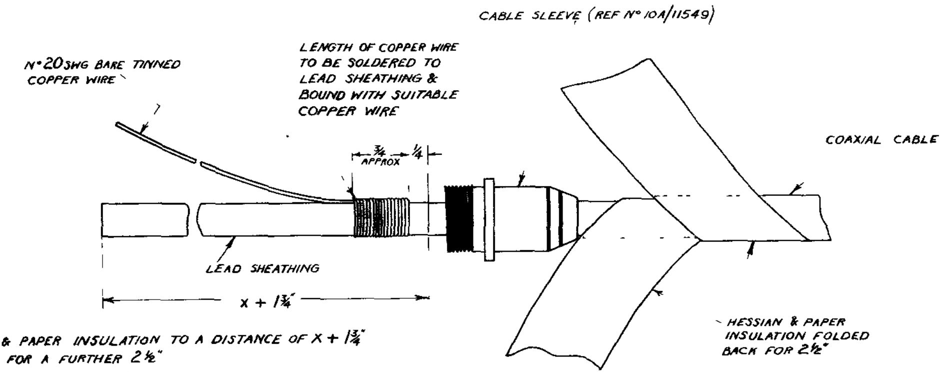
METER FOR MEASURING STANDING WAVES. GENL ARRGT & DETAILS.

DRAWN	TRACED	CHECKED	APPROVED	DATE
MB	SH			5 11 42

DRG. Nº WT 50495.

40"X30"

ISSUE 1
DATE
CHANGES

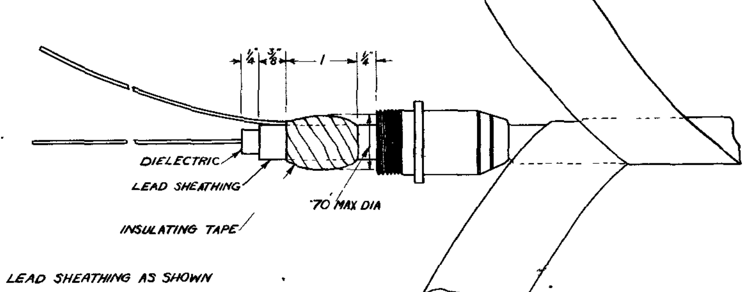


(a) Cut back hessian & paper insulation to a distance of X + 1¾" & then fold back for a further 2½"

(b) Put cable sleeve (Ref. Nº 10A/11549) on cable as shown

(c) Nº 20 SWG bare tinned copper wire Y + 1½" long to be soldered to lead sheathing as shown

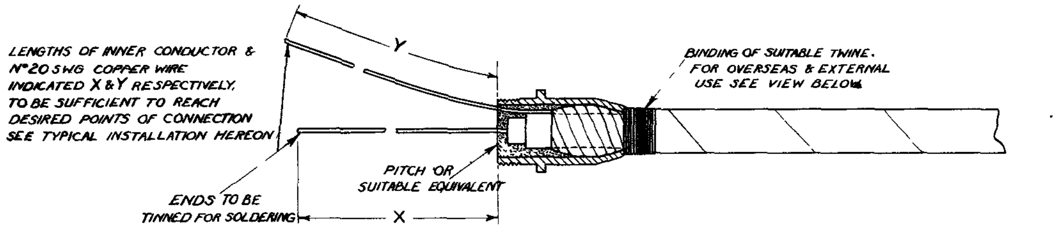
Note – For dims X & Y see lower view



(d) Bind insulating tape round lead sheathing as shown

(e) Cut lead sheathing back to within ⅜" of insulating tape as shown

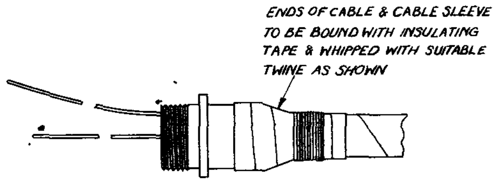
(f) Cut dielectric back to within ¼" of lead sheathing as shown



(g) Pull cable sleeve (Ref Nº 10A/11549) firmly over insulating tape

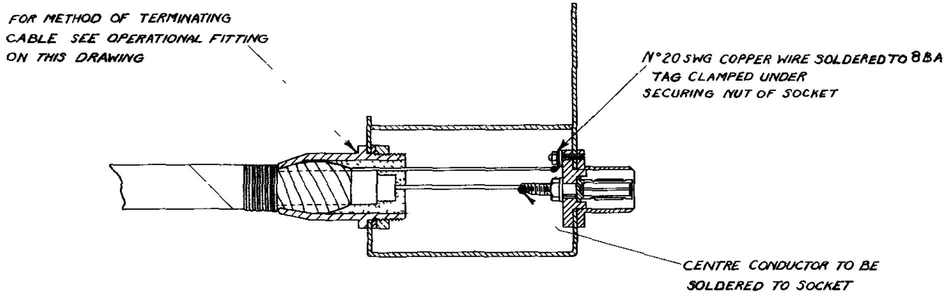
(h) Fill in cable sleeve with pitch or suitable equivalent as shown

(k) Outer insulation to be folded back in position to end of cable sleeve & bound with suitable twine

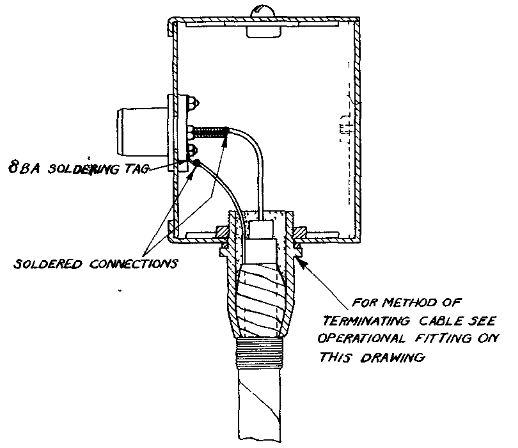


View Showing Method of Weatherproofing Cable Entry for External & Overseas Use

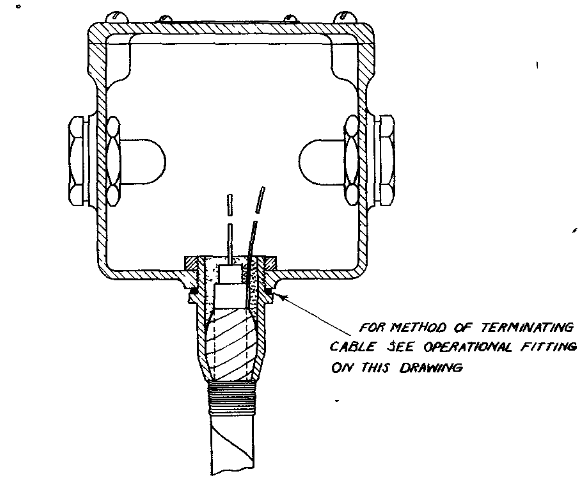
Operations for Fitting Coaxial Cable in Cable Sleeve Ref Nº 10A/11549



Typical Installation of Coaxial Cable to Distribution Panel Drg. Nº WT 50392



Typical Installation of Coaxial Cable to Distribution Box Type 3



Typical Installation of Coaxial Cable in Box Ref Nº 10A/11553

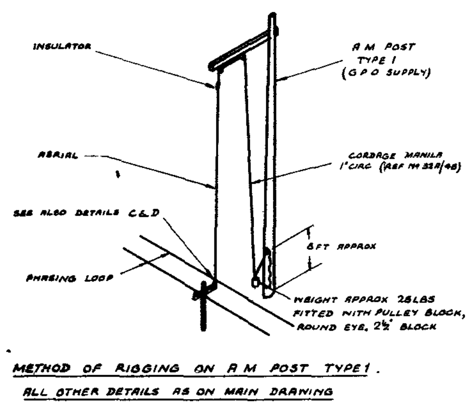
Issued by
D of Tels
Tels 3E
Air Ministry

Termination of Unarmoured Lead Sheathed Coaxial Cables (Small)

DRAWN	TRACED	CHECKED	APPROVED	DATE
AHB	SH	JH	LHG. J McHolding	28.9.42 23.1.42

Drg. Nº W. T. 50502.

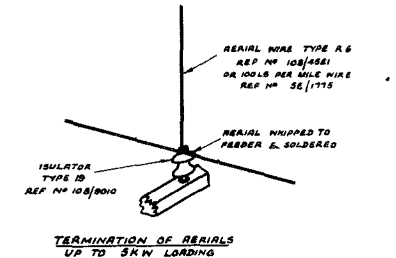
37½" x 27"



METHOD OF RIGGING ON A M POST TYPE 1.

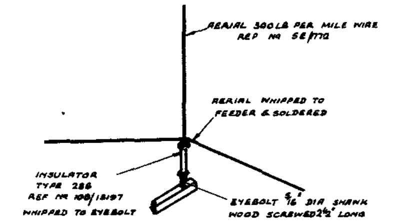
ALL OTHER DETAILS AS ON MAIN DRAWING

DETAIL A



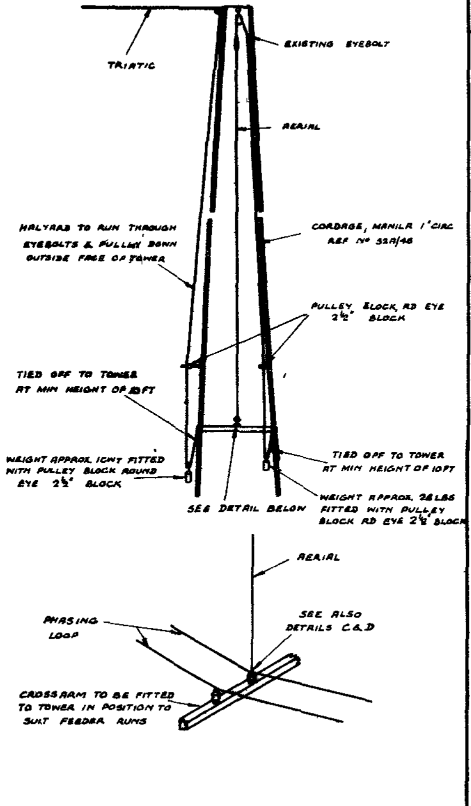
TERMINATION OF AERIALS UP TO 5 KW LOADING

DETAIL C



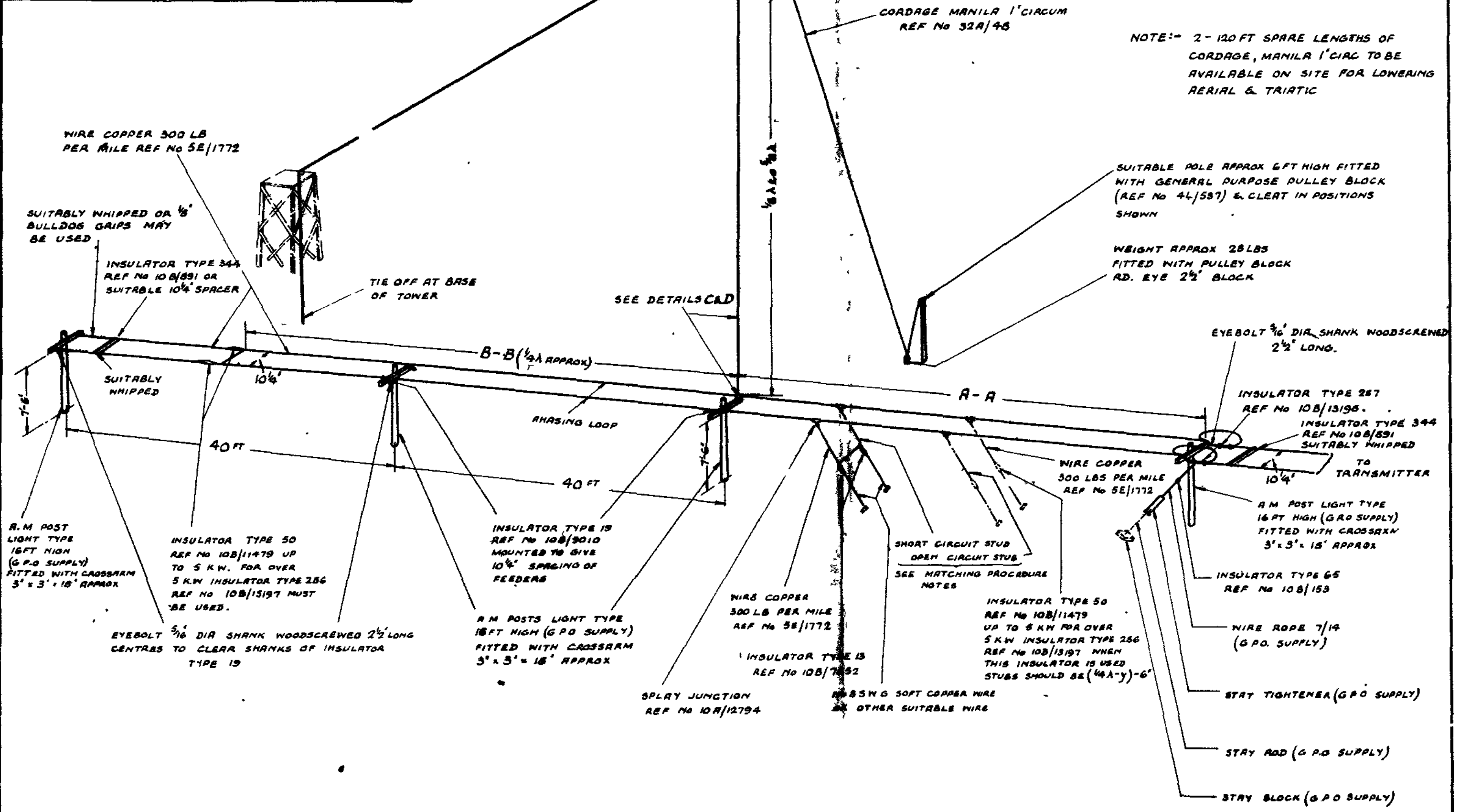
TERMINATION OF AERIALS OVER 5 KW LOADING

DETAIL D

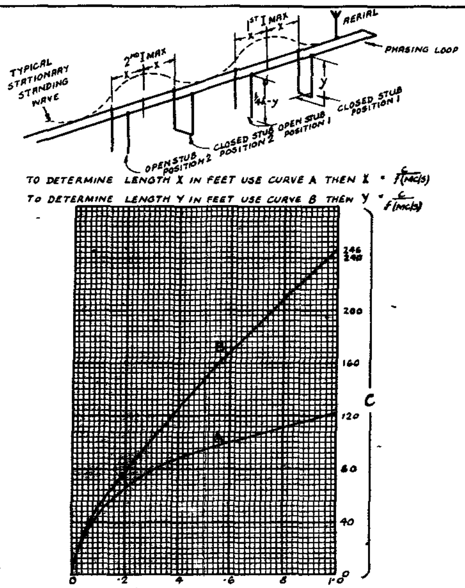


VIEW SHOWING METHOD OF RIGGING AERIAL IN TOWER & METHOD OF WEIGHTING TRIATIC (ALL OTHER DETAILS AS ON MAIN DRG.)

DETAIL B.



NOTE:- 2 - 120 FT SPARE LENGTHS OF CORDAGE, MANILA 1" CIRC TO BE AVAILABLE ON SITE FOR LOWERING AERIAL & TRIATIC



TO DETERMINE LENGTH X IN FEET USE CURVE A THEN $X = \frac{C}{f(Mc/s)}$

TO DETERMINE LENGTH Y IN FEET USE CURVE B THEN $Y = \frac{C}{f(Mc/s)}$

CURVE FOR DETERMINING LENGTHS & POSITIONS OF OPEN & CLOSED CIRCUIT STUBS

MATCHING PROCEDURE FOR 1/8 λ TO 5/8 λ AERIALS

① WITH TRANSMITTER ON LOW POWER & USING STANDING WAVE METER WT 50495 DETERMINE CURRENT ALONG SECTION A-A (SEE MAIN DRG) AS FOLLOWS –
  - (a) ALONG FEEDER LEG TO WHICH AERIAL IS ATTACHED, STARTING AT AERIAL, MOVE METER TOWARDS TRANSMITTER UNTIL MAX CURRENT (I MAX) POSITION IS REACHED, REPEAT ON OTHER LEG ADJUSTING LENGTH OF B-B (SEE MAIN DRG) UNTIL I MAX POINTS ARE OPPOSITE (SEE NOTE b) MARK THESE POINTS, NOTING I MAX VALUE
  - (b) TO MAKE I MAX POINTS OPPOSITE ALONG FEEDER LEGS, LENGTH B-B (SEE MAIN DRG) SHOULD BE SHORTENED OR INCREASED BY HALF THE DISTANCE BETWEEN THE TWO I MAX POINTS IE INCREASED IF THE SECOND READING IS NEARER THE TRANSMITTER THAN THE FIRST & VICE VERSA
  - (c) HAVING FOUND POSITION OF I MAX SLIDE METER ALONG EITHER LEG OF FEEDER TO DETERMINE VALUE OF I MIN

② TO DETERMINE VALUE OF X & Y (DIAGRAM ABOVE).
  - (a) OBTAIN RATIO OF I MIN/I MAX
  - (b) USING RATIO OBTAINED IN (a) DETERMINE CONSTANTS C FROM GRAPH ABOVE
  - (c) INSERT CONSTANTS IN FORMULÆ ABOVE GRAPH

③ USING OBTAINED VALUES OF X & Y CONSTRUCT & LOCATE STUB AS INDICATED IN DIAGRAM ABOVE & NOTE 4 BELOW

④ POSITION & TYPE OF STUB:- IN GENERAL, CHOOSE STUB CLOSEST TO AERIAL IE
FOR 3/8 λ & ½ λ AERIALS, USE CLOSED STUB IN POSITION 1
FOR 1/8 λ & 5/8 λ AERIALS, USE CLOSED STUB IN POSITION 1, IF X IS LESS THAN 1/8 λ USE OPEN STUB POSITION 1.
FOR ¼ λ AERIAL, USE CLOSED STUB POSITION 2

NOTE

AERIAL MAY BE OF ANY LENGTH BETWEEN 1/8 λ & 5/8 λ. FOR OPTIMUM LOW ANGLE RADIATION & MINIMUM FADING, LENGTH SHOULD BE ·56 λ; IF LIMITED BY MAST HEIGHT, THEN AS HIGH AS POSSIBLE

ISSUE	1
DATE	28-9-42
CHANGES	

ISSUED BY
D OF TELS

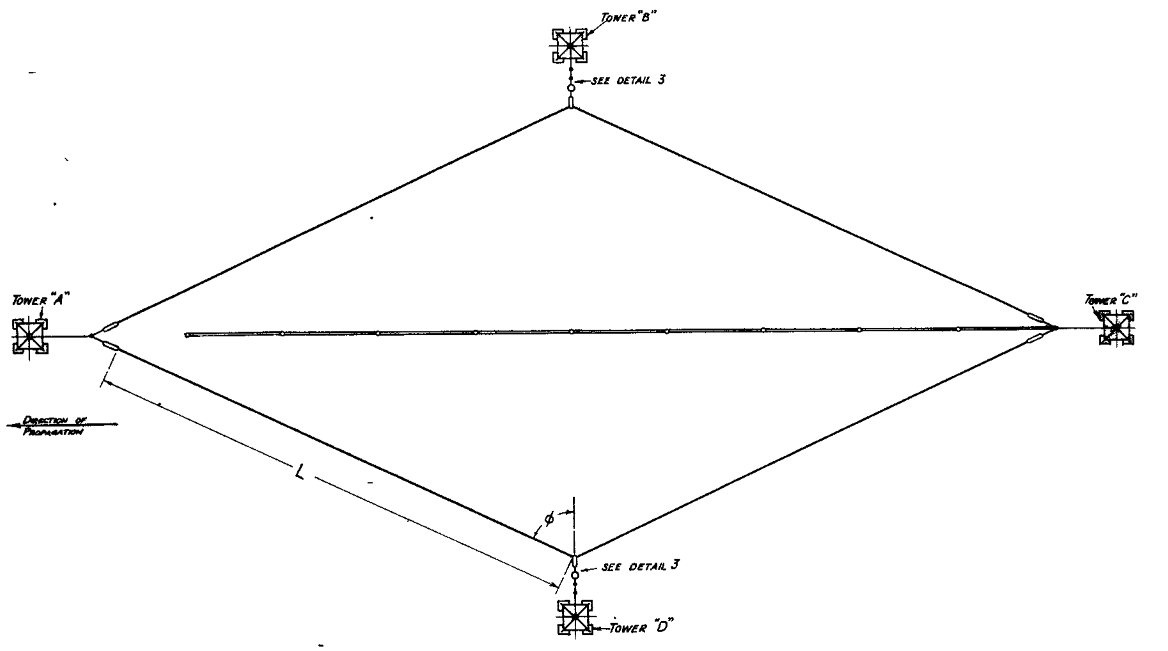
AIR MINISTRY

TYPICAL INSTALLATION & MATCHING DETAILS FOR VERTICAL REMOTE AERIALS. (1/8 λ TO 5/8 λ)

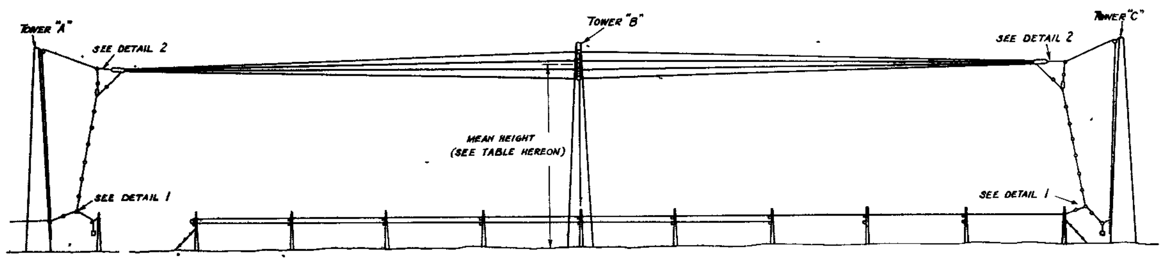
DRAWN	TRACED	CHECKED	APPROVED	DATE
H.T		J.G.B. 25 9-42	L.A.G S.W.H	24.9-42 24-9-42

DRG. No WT 50457.

26" x 15"



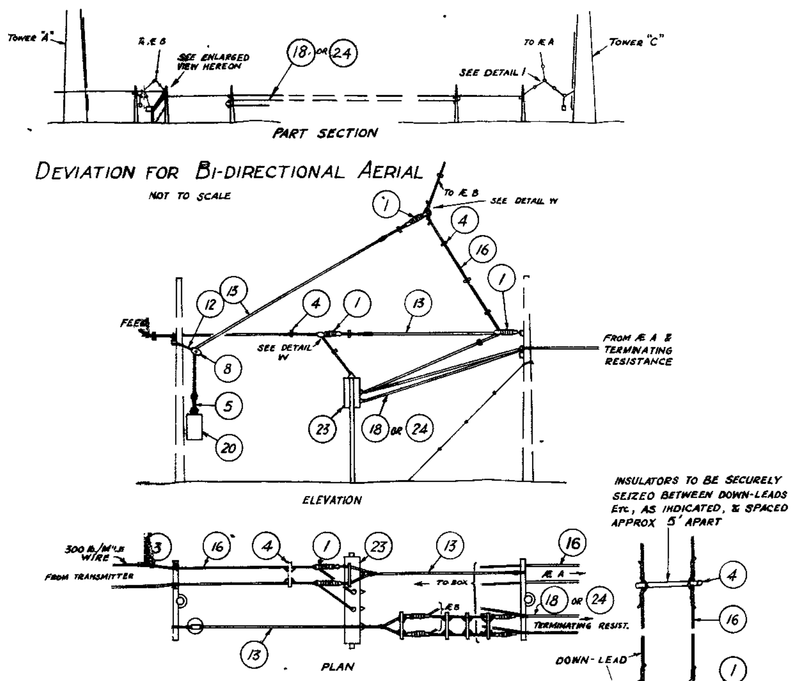
PLAN



PART SECTION

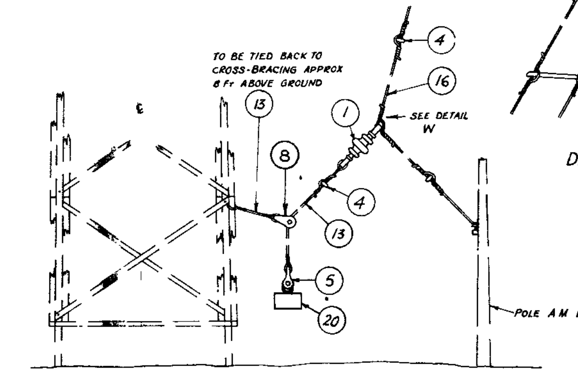
G.A OF UNI-DIRECTIONAL AERIAL

DEVIATION FOR BI-DIRECTIONAL AERIAL SEE VIEW HEREON



DEVIATION FOR BI-DIRECTIONAL AERIAL

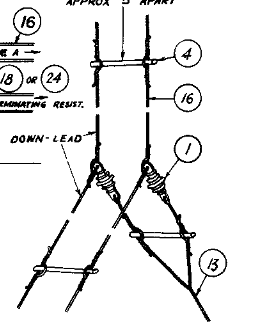
NOT TO SCALE



RIGGING DETAILS WHEN DOWN-LEAD TERMINATES AT BASE OF AERIAL

DETAIL I

NOT TO SCALE

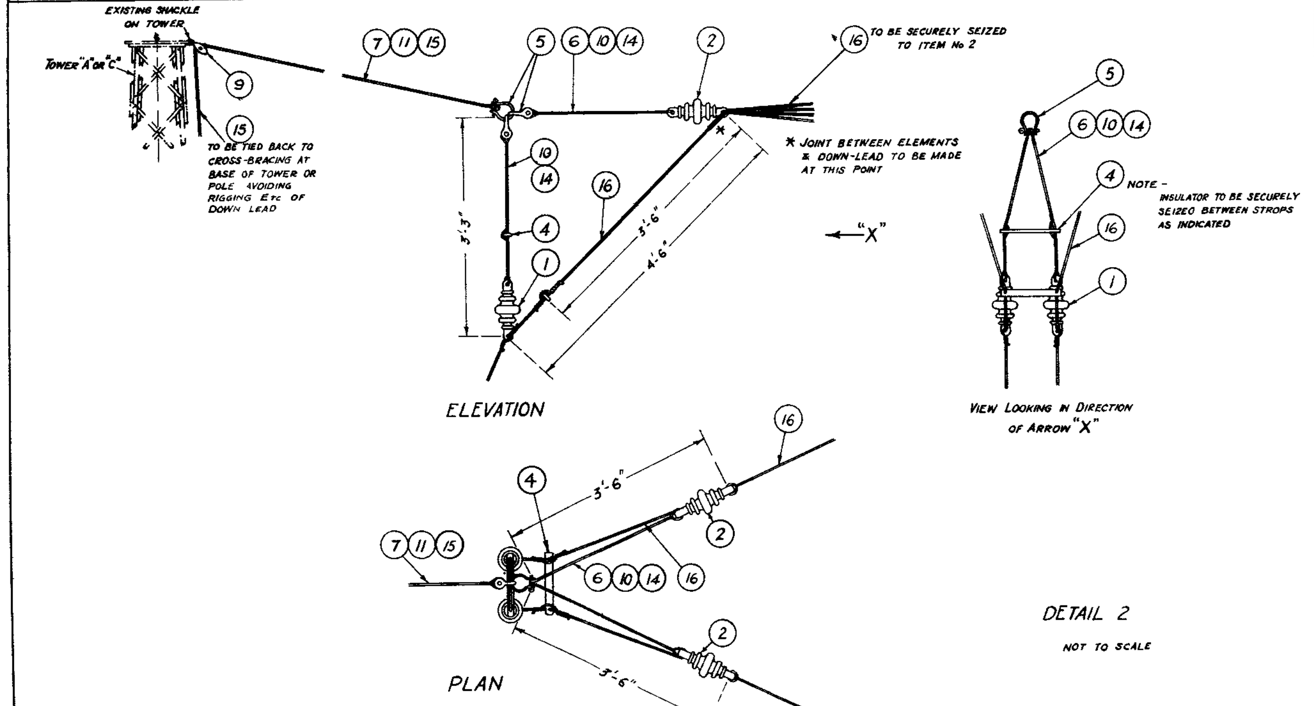


DETAIL W

ITEM No	DESCRIPTION	Q'TY	DRAWING No	REF No	REMARKS
1	INSULATOR TYPE 13	24		10B/7652	
2	INSULATOR TYPE 50	4		10B/11479	
3	INSULATOR TYPE 344	1		10B/891	
4	INSULATOR TYPE 375	SEE TABLE		10B/1194	INSULATOR TYPE 68 REF No. 10B/156 MAY BE USED
5	SHACKLE BOW "HARP" SHAPE 3/8" DIA	18			CAT No 1221 } DAVEY & Co
6	BULLDOG WIRE ROPE GRIPS 1/8" DIA	200			CAT No 1624 } (LONDON) LTD
7	BULLDOG WIRE ROPE GRIPS 1/4" DIA	24			CAT No 1624 } OR L P O
8	PULLEY BLOCK ROUND EYE 2½"	6			CAT No. 482 }
9	BLOCK G P SINGLE	4		4L/537	
10	THIMBLE NON-CORRODIBLE STEEL	42		28C/6069	
11	THIMBLE NON-CORRODIBLE STEEL	8		28C/6072	
12	THIMBLE NON-CORRODIBLE STEEL	2		28C/6074	
13	CORDAGE MANILA 1" CIRCUM	30 FATHOMS		32A/48	
14	WIRE ROPE FLEXIBLE ½" CIRCUM	20 FATHOMS		29/2069	
15	WIRE ROPE FLEXIBLE ¾" CIRCUM	SEE TABLE		29/2071	
16	WIRE COPPER H D	SEE TABLE		5E/1775	100 LB/MILE
17					
18	WIRE NICKEL CHROME 14 SWG	SEE TABLE			
19	SPREADER TYPE 38 3FT COMPLETE	2		10B/1210	
20	AERIAL WEIGHT 14 lb	2	WT 50464		
21	AERIAL WEIGHT 112 lb	4	WT 50464		
22					
23	CHANGE OVER SWITCH FOR RHOMBIC Æ	1	WT 50542		
24	WIRE STEEL GALVANIZED 14 SWG	SEE TABLE			TO BE USED ONLY WHEN ITEM No 18 IS NOT AVAILABLE
25					
26					
27					
28					
29					
30					

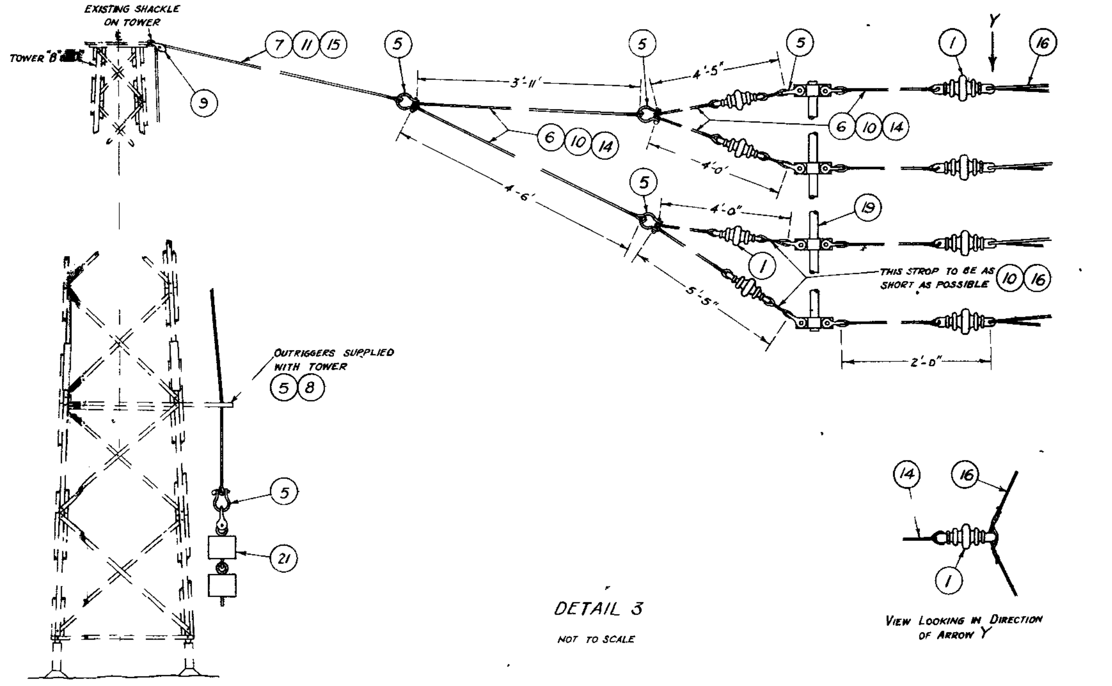
Æ TYPE	F'Q'CY M c/s	TOWERS OR POLES			AERIAL					TERMINATING RESISTANCE		QUANTITY OF ITEM No.		
		HEIGHT	SPACING MAJOR AXIS	SPACING MINOR AXIS	HEIGHT ABOVE GROUND	MAJOR AXIS	MINOR AXIS	L	ϕ	LENGTH OF ITEM No 18	LENGTH OF ITEM No 24	4	15	16
A	6-12	90'	770'	366'	85'	731'	325'-6"	400'	66°	1100'	5500'	44	35 FATHOMS	2,300 YDS
B	7-15	70'	644'	297'	65'-6"	604'	256'-6"	328'	67°	610'	3050'	32	30 FATHOMS	1900 YDS
C	10-20	55'	493'	232'	49'	453'	192'	246'	67°	460'	2300'	26	25 FATHOMS	1,500 YDS

NOTE – WHERE A M POSTS TYPE 4 ARE USED IN PLACE OF TOWERS BACKSTAYS MUST BE FITTED



DETAIL 2

NOT TO SCALE



DETAIL 3

NOT TO SCALE

CHANGES
DATE - 27 11 42
ISSUE No 1

ISSUED BY

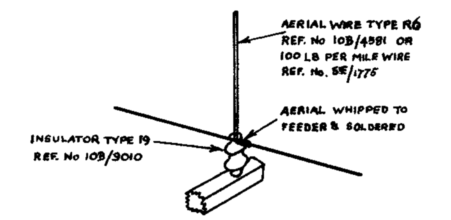
D OF TELS

A M

AERIAL. RHOMBIC. 4 WIRE. TRANSMITTING STANDARD.

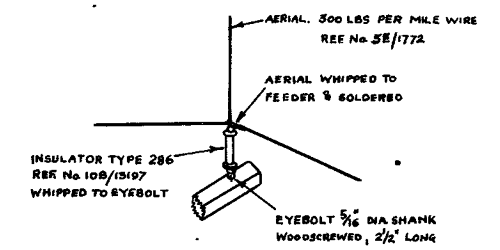
DRAWN	TRACED	CHECKED	APPROVED	DATE
J F G	J F G	J G B.	S W Holding	27 11 42

DRG. No. WT 50496



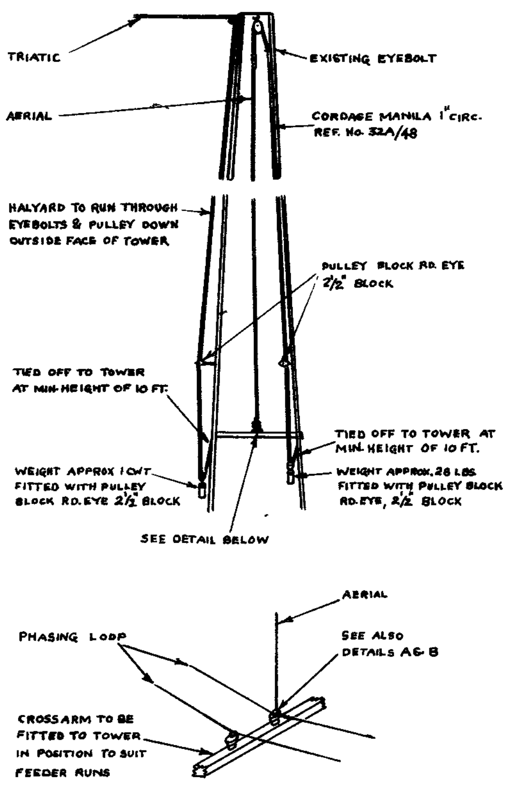
TERMINATION OF AERIALS UP TO 5 KW. LOADING

DETAIL A



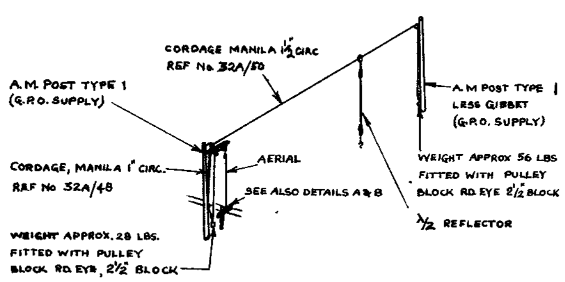
TERMINATION OF AERIALS OVER 5 KW. LOADING

DETAIL B



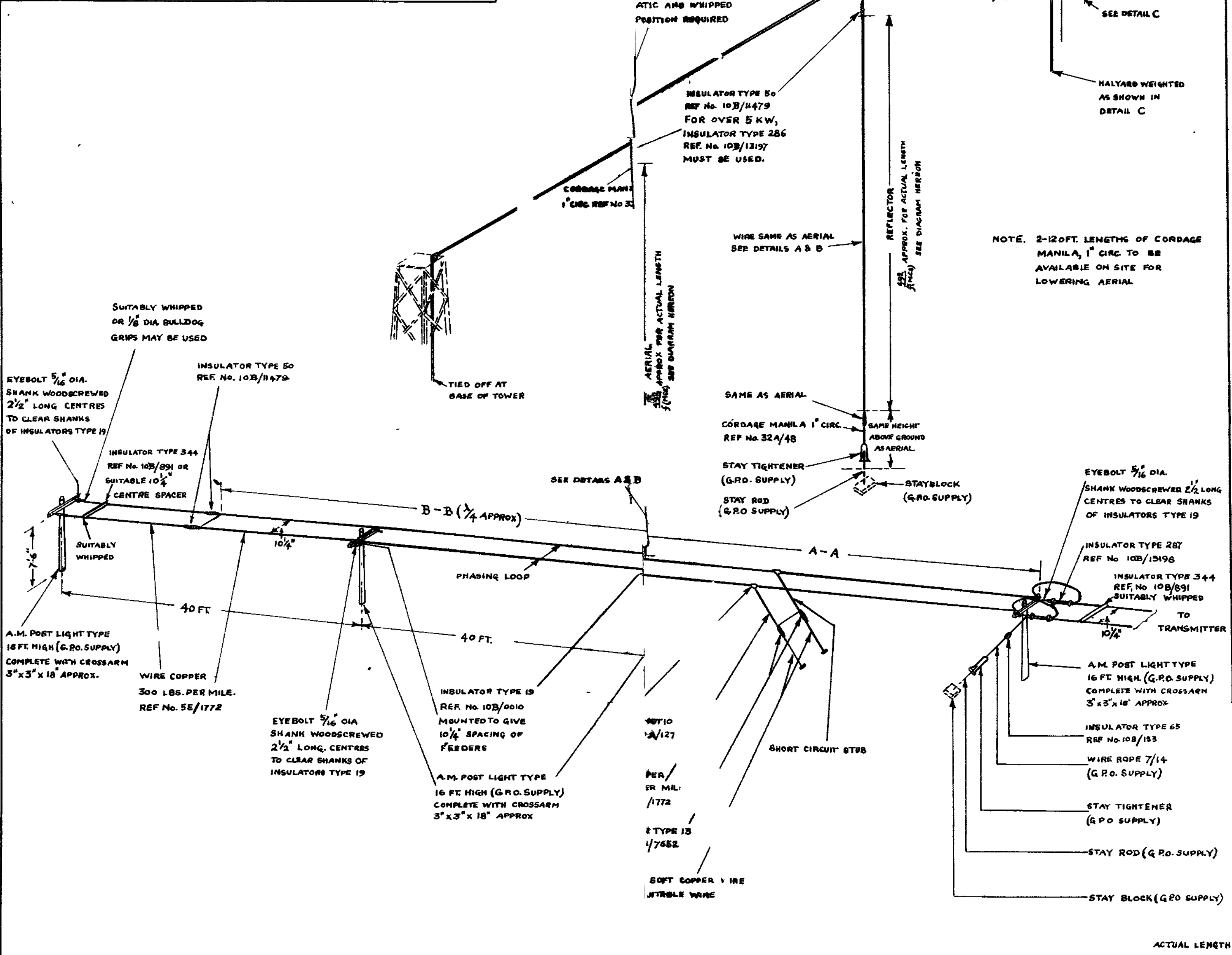
VIEW SHOWING METHOD OF RIGGING AERIAL
IN TOWER & METHOD OF WEIGHTING TRIATIC
(ALL OTHER DETAILS AS ON MAIN DRAWING)

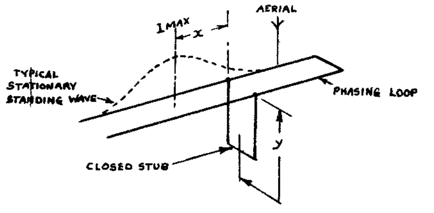
DETAIL C



METHOD OF ERECTING VERTICAL λ/2 AERIAL WITH
REFLECTOR ON 2 A.M. POSTS TYPE 1
(ALL OTHER DETAILS AS ON MAIN DRAWING)

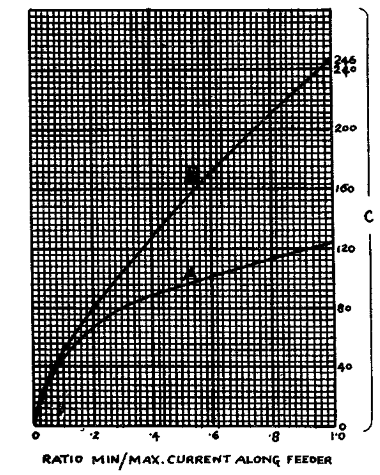
DETAIL D





TO DETERMINE LENGTH x IN FEET USE CURVE A THEN $x = \frac{c}{f(\text{MCS})}$

TO DETERMINE LENGTH y IN FEET USE CURVE B. THEN $y = \frac{c}{f(\text{MCS})}$

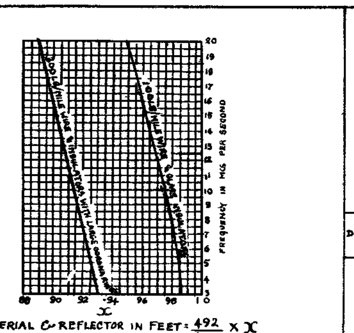


RATIO MIN/MAX. CURRENT ALONG FEEDER

CURVE FOR DETERMINING LENGTHS AND POSITION OF CLOSED CIRCUIT STUB

MATCHING PROCEDURE

1. WITH TRANSMITTER ON LOW POWER AND USING STANDING WAVE METER WT 50495 DETERMINE CURRENT ALONG SECTION A-A (SEE MAIN DRG) AS FOLLOWS:-
   - (a) COMMENCING AT AERIAL, MOVE METER ALONG FEEDER LEG TO WHICH AERIAL IS ATTACHED, IN THE DIRECTION OF TRANSMITTER UNTIL MAX CURRENT (I MAX.) POSITION IS REACHED. REPEAT ON OTHER LEG ADJUST LENGTH OF B-B (SEE MAIN DRG) UNTIL I MAX. POINTS ARE OPPOSITE (SEE NOTE b). MARK THESE POINTS, NOTING I MAX. VALUE
   - (b) TO BRING I MAX. POINTS OPPOSITE ALONG FEEDER LEGS, LENGTH BB (SEE MAIN DRG.) SHOULD BE SHORTENED OR LENGTHENED BY HALF THE DISTANCE BETWEEN THE TWO I. MAX. POINTS i.e. LENGTHENED IF THE SECOND READING IS NEARER THE TRANSMITTER THAN THE FIRST & VICE VERSA
   - (c) HAVING FOUND POSITION OF I MAX SLIDE METER ALONG EITHER LEG OF FEEDER & DETERMINE VALUE OF I MIN.
2. TO DETERMINE VALUE OF x AND y (DIAGRAM ABOVE)
   - (a) OBTAIN RATIO OF I MIN./I MAX.
   - (b) USING RATIO OBTAINED IN 2(a) DETERMINE CONSTANTS C FROM GRAPH ABOVE.
   - (c) INSERT CONSTANTS IN FORMULÆ ABOVE GRAPH
3. USING OBTAINED VALUES OF x AND y, CONSTRUCT & LOCATE STUB AS INDICATED IN DIAGRAM ABOVE.



ACTUAL LENGTH OF AERIAL & REFLECTOR IN FEET $= \frac{492}{f(\text{MCS})} \times X$

CHANGES
DATE 28·?·42
ISSUE 1

ISSUED BY
D. OF T.
TELS 3E
A.M.

TYPICAL INSTALLATION & MATCHING DETAILS FOR VERTICAL AERIAL WITH REFLECTOR

DRAWN	TRACED	CHECKED	APPROVED	DATE
		J.G.B. 25·9·42	L.M.G. S.N. Kiddry	28·9·42 26·9·42

DRG. No. WT 50467