A D F Installations

By P P CREEK

Mr Creek joined Marconi's Wireless Telegraph Co Ltd, in 1952 He has specialised in the problems of A D F installations in all types of aircraft He served in the R A F from 1941 and rejoined again in 1947, specialising in radio installation problems

The Automatic Direction Finder is a primary radio navigational aid, providing a pilot or operator with a direct indication of the relative bearing of any radio transmitter to which the equipment is tuned, normally in the band 150 to 1,800 Kc/s

Using a single transmitter the co-ordinates of which are known, a simple homing can be obtained and with the use of two or more transmitters it is possible to obtain a position fix

To this end small beacon transmitters are often installed at airfields Most homing procedures terminate with the passage of the aircraft over the top of the beacon and this is indicated by a reversal of the bearing indicator needle

The basic elements of the complete A D F installation are a directional or loop aerial, a non-directional or sense aerial, a receiver and a bearing indicator Most modern equipments have an arrangement whereby control of the receiver and, when necessary, manual control of the loop can be carried out remotely by the addition of small units within easy reach of the pilot or operator

The all up weight of an installation can be as low as 20 pounds

The main difficulties encountered with this type of installation in a helicopter centres round the positioning of the two aerials

The factors which determine the choice of the position for the directional aerial are

(1) It should be sited on the surface of the aircraft skin, approximately in the centre of plan area, on the fore and aft line of the aircraft
(2) It should be as far as possible from surface discontinuities
(3) It should be as far as possible from the rotor assembly
(4) It should be sited as far as possible from projections, such as derricks, which may contain closed loops of electrical conducting material
    This particularly applies where these projections are movable or removable
(5) Ideally the directional aerial should be on the skin surface In the case of suppressed aerials it should be buried no further than is necessary
(6) It should be mounted as far as possible from sources of electrical noise

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The factors which determine the choice of position for the non-directional aerial are —

(A) It should be as near as possible to the centre of plan area

(B) It should be as far as possible from the rotor assembly

(C) It should be as far as possible from large projections from the main body of the aircraft, such as metal floats

(D) It should be as far as possible from sources of electrical noise

Of the factors previously mentioned which determine the position of the directional aerial, the first four primarily affect the ultimate accuracy Normal airworthiness requirements demand that the bearings obtained should be accurate to within $\pm 2°$, despite the difficulty of holding a helicopter heading with this precision

Modern equipments are capable of an instrumental accuracy of about $\pm 1°$ and our aim should be to approach this figure on the initial calibration

Errors in the bearing information received from the directional aerial fall into two main categories, constant errors and variable errors Constant errors usually encountered are those due to maladjustment of the directional aerial on the fore and aft line and those due to the distortion of the field surrounding the loop by the aircraft's cylindrical form The former can easily be avoided by the provision of a fore and aft datum for physical adjustment of the loop The latter is in quadrantal form and can be analysed as the resultant of two fields which can be corrected for after calibration

The variable errors are a little more difficult to analyse, but usually they follow semi-circular form, namely in that only two maxima occur in a compete 360° rotation This variable error is generally caused by siting the loop in a position where close coupling to a projection produces distortion of the field, which varies with frequency

One such position on a helicopter is near the rotor assembly Installations in which the directional aerial is mounted too close to the rotor suffer from bearing inaccuracies varying with frequency of the received signal and with rotor position

To give an example of the way in which constant and variable errors

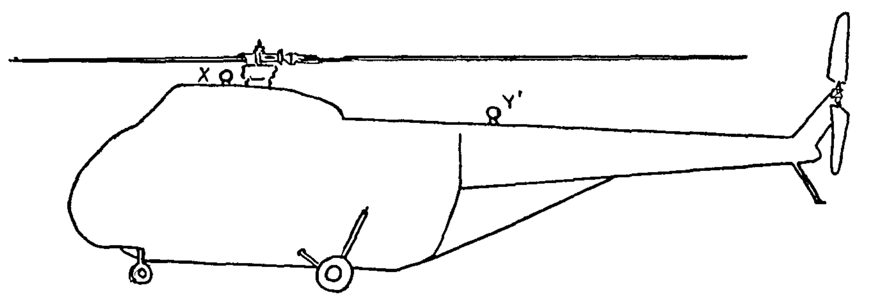

Fig 1 Helicopter Shape Showing Experimental Directional Aerial Positions 'X' and 'Y'

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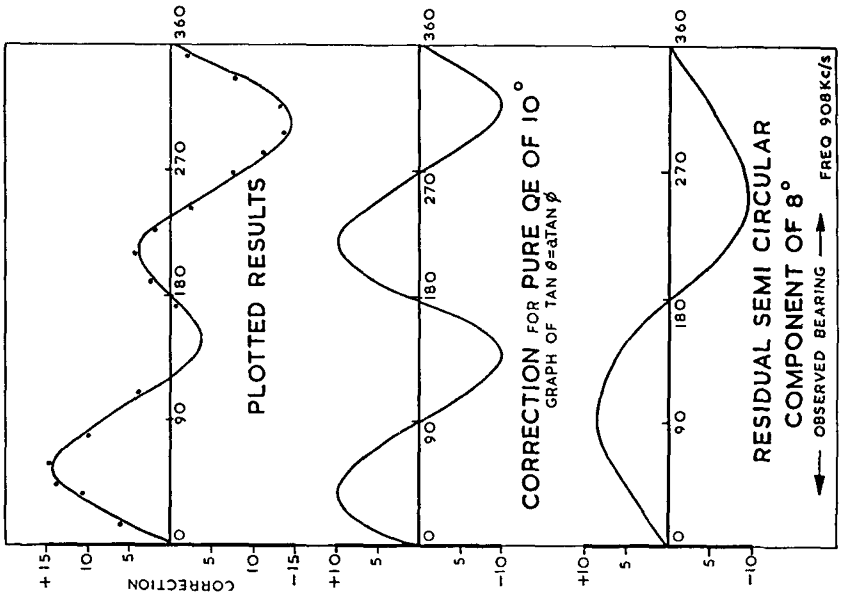
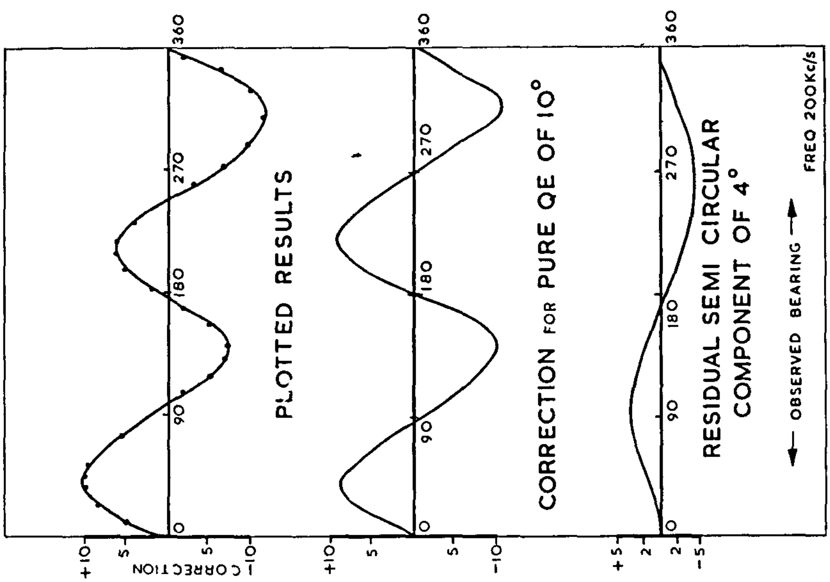


GRAPH X 2



GRAPH X'1

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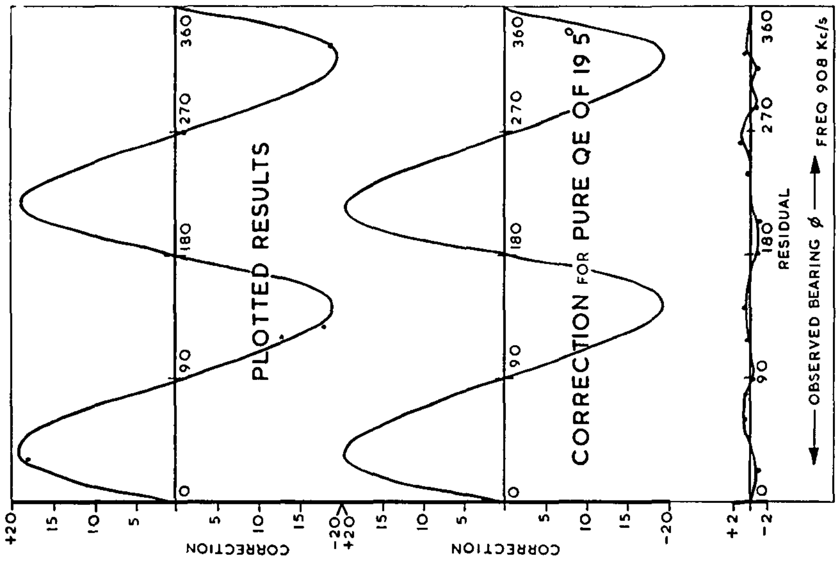
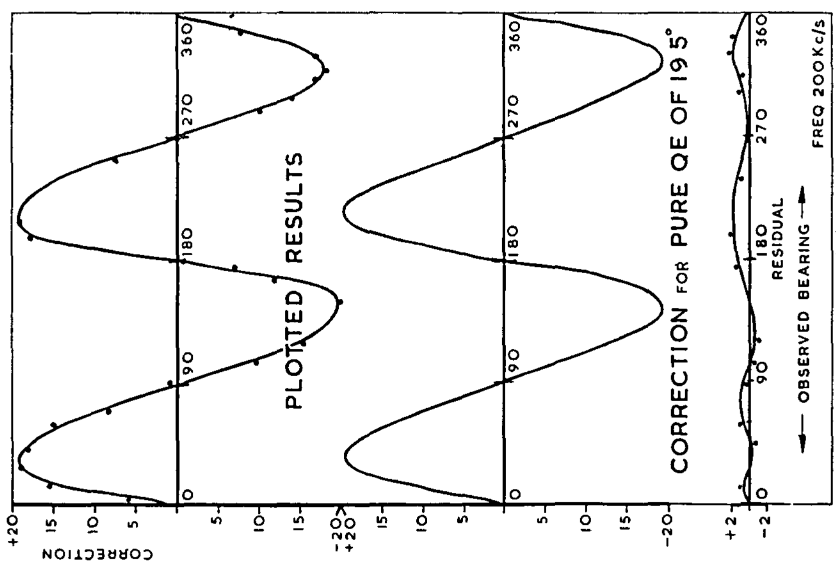


GRAPH 'Y' 2



GRAPH 'Y' 1

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can vary with respect to fuselage curvature and proximity to the rotors assembly, I would refer you to Fig 1, a sketch of a helicopter with directional aerial test positions shown as X and Y

Position X was checked on two frequencies 200 and 908 Kc/s with the results as shown in graphs X1 and X2 It can be seen that the results are variable with frequency, namely in that a constant or pure quadrantal error has superimposed upon it a semi-circular error which increases with frequency

Position Y was swung on the same frequencies and the results are shown on graphs Y1 and Y2 Here the quadrantal error has increased with fuselage curvature, but has remained almost pure in form up to the highest frequency used The fact that the quadrantal error is greater in magnitude is of little consequence as it can be corrected by an error corrector mechanism following a pure quadrantal law

Note that the pure Q E is not sinusoidal, the maxima occurring at $45 - E/2$, $135 + E/2$, $225 - E/2$ and $315 + E/2$

For convenience all results and theoretical curves are plotted against the observed bearing and shown as the correction required for a particular reading

From the point of view of rotor position the results illustrated were taken under static conditions Under operational conditions the rear position Y suffered less from modulation effects and random errors than did position X The overall operational accuracy with position Y was of the order of ± 3 degrees

The remaining two factors affecting the position of the directional aerial determine the range at which useful bearings are obtained from the transmitter An aircraft flying away from the transmitter to which the ADF is tuned reaches a point where the bearing indicator needle begins to move in an erratic fashion The aircraft has then reached the maximum usable range of that beacon The greater the electrical noise picked up by the directional aerial the greater is the reduction of the useful range of the station If the directional aerial is suppressed in the skin of the aircraft, the greater the depth of the aerial below the surface the greater is the reduction on useful range It may be as well to point out that there are various hidden sources of electrical noise on an aircraft such as a discontinuity in the metal skin where perspex or other insulating material is inserted or sharp points which lead to electrical discharge in flight

The crew of an aircraft approaching a transmitter have to tune the ADF and identify the call sign of the beacon Here then the range is not only determined by obtaining effective bearings but also by the ability to read the identification code The range at which a transmitter can be identified is largely determined by the performance of the non-directional aerial If this aerial is sited so that it picks up excessive electrical noise or so that its pick up is reduced by its environment then the range will be materially effected For example if the aerial is placed near the rotor blades then the incoming signal will be modulated by their rotation which in turn will affect the ability of the operator to read distant signals This aerial is

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also the most vulnerable part of the installation to the effects of precipitation static Precipitation static is the name given to the noise produced in a receiver when the aircraft flies through those meteorological conditions which produce intense electrical charges on the aircraft This static electricity leaks away into the atmosphere through projections and sharp points on the air frame

The non-directional aerial of necessity is itself one of these projections and steps have to be taken to minimise the discharge through it, by fitting wick dischargers to reduce the charge on the airframe and by shaping the aerial to raise the voltage required for the onset of corona

The position of this aerial on the fore and aft line of the aircraft affects the behaviour of the A D F during passage of the aircraft over the transmitter If it is not positioned correctly the bearing indicator needle can reverse before or after the aircraft passes the geographical position of the transmitter, or may move erratically in the vicinity of the transmitter

The best position for both aerial systems is to be found on the underside of the fuselage or where there is the largest area, uncluttered by projections The directional aerial would be placed on the fore and aft line of the fuselage, approximately amidships In the case of suppressed aerials, this involves cutting a hole in the skin about 18″ diameter, or in the case of the more recent fixed loops, fixing a small unit about $\frac{5}{8}$″ thick to the outside of the skin with only a small hole for the cables

The ideal non-directional aerial usually takes the form of a horizontal $\frac{1}{2}$″ rod between 4 and 10 ft long, mounted on two or three pillars 4 to 10″ in height This is mounted with the rod in line with and on the fore and aft datum of the fuselage, away from sharp projections

These positions are rarely available on a helicopter for the aerials owing to the space being required for floats, store carriers and the like It is, therefore, essential that at the time of designing the A D F installation precise information is available on the position and size of all external fittings and accessories and that these should be present when the installation is first tested Usually the directional aerial has to be sited on top of the fuselage and it has been found that a position aft of the rotor head is electrically superior to a position forward of it

The non-directional aerial frequently has to be moved aft of the ideal position on the bottom of the fuselage and this usually leads to the bearing indicator needle reversing after the aircraft has passed over the transmitter

It is important when arranging the run of the cables to the two aerials that they be adequately separated from sources of electrical interference, such as generators, motors and cables running to and from them

In spite of the difficulties in engineering the installation of an Automatic Direction Finder in a helicopter, there is little doubt, because of its low cost and weight penalty, and its operational simplicity and versatility, that it will remain the primary navigational aid for many years to come

I wish to record my thanks to the Engineer-in-Chief, Marconi's Wireless Telegraph Company Ltd , for permission to present this paper

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