presents no problems for the obvious reason of their being accessible by their very use V H F whip aerial bases should be capable of visual inspection and quick replacement Under icing conditions aerial damage is not uncommon

Conclusion

The foregoing are the fundamental requirements for a radio communications installation and most of the points I have raised apply to radio equipment generally In the past, it has been the custom to design and build an aircraft and then endeavour to fit the radio in as best possible This system is technically frustrating and economically unsound Aircraft radio has for too long laboured under the derogatory misnomer of an ancillary equipment The dictionary definition of ancillary is " subservient " and although in the early days radio was not essential and was considered a luxury perhaps, it is now part and parcel of aircraft operation and its integration into the design pattern of an aircraft should be considered at a very early stage Not being aircraft designers ourselves we cannot precisely specify the how and the where of a particular installation, but we do pass to you our recommendations for successful radio operating for your contemplation, comment, and we trust co-operation

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Aerial Systems *

By R A Burberry

Mr Burberry has been with Standard Telephones and Cables Ltd since 1947 in charge of a group working on aircraft aerials Previously he had been with Telecommunications Research Establishment He has been continuously engaged on the design and development of aircraft aerials

Without a good aerial system an Aircraft Radio Equipment is about as useful as a helicopter without a rotor and yet it still happens that the proper provision and siting of aerials is neglected The intention of this paper is to outline the basic requirements of aerials for the radio systems in general used on helicopters and to show how the difficulties peculiar to this class of aircraft can be overcome

Classification

For the purposes of this discussion three broad categories of radio equipment can be distinguished These are

1 Low frequency—*i e*, up to 2 Mc/s or wavelengths greater than 150

* This paper embodies material gathered by the author in the course of his work at Standard Telephones and Cables to whom the author's thanks are due

https://doi.org/10.1017/S2753447200003668 Published online by Cambridge University Press

meters In this range the major aircraft dimensions are much less than the wavelength

2 High frequency (H F) 2 to 30 Mc/s or wavelengths of 150 to 10 meters in which the aircraft size is becoming comparable with the wavelength

3 Very High frequency (V H F), 100 to 300 Mc/s wavelength to 1 meter where the major aircraft dimensions are appreciably greater than the wavelength but where cross-sectional dimensions may be of the same order

The behaviour of a particular aerial system on an aircraft is determined by this relation between aircraft size and wavelength in a manner which will be explained below

Aerial Efficiency

The quality of an aerial can be assessed in terms of three factors — Impedance, Radiation Pattern, and Gain, each of which will be briefly considered

Impedance

In general an aerial cannot be connected directly to its associated radio equipment and a transmission line is needed between the two Radio frequency cables or transmission lines in aircraft are, with a few exceptions, of the co-axial type and consist of a copper inner conductor surrounded by a low-loss dielectric and a concentric metallic braid To every transmission line can be assigned a parameter known as its characteristic impedance , this is determined by the dimensions and construction of the line The significance of characteristic impedance is that if power is fed into one end of the line which is terminated at its other end by a resistance equal to the characteristic impedance all the power reaching the load will be absorbed and none will be reflected to the transmitter In fact some of the power will be absorbed en route by the cable length and increasing with frequency There may, therefore be a limitation in the relative position between a radio equipment and its aerial because of the cable loss

Most radio equipments are designed to be used with cables of a particular impedance and for the maximum transfer of power the aerial must be designed to match the cable as well as possible A measure of the quality of this impedance matching is the voltage standing wave ratio (V S W R), unity V S W R implying a perfect match A better standard of matching is required with a radio transmitter than with a receiver, typical limits being V S W Rs of 2 to 1 and 5 to 1 respectively

Radiation Pattern

The spatial distribution of radiated energy required from an aerial depends on the function of the radio equipment For communications uniform coverage in azimuth is necessary with most of the energy concentrated within small angles of elevation and depression from the azimuth Energy radiated vertically upward is unwanted and since the maximum altitude of the helicopter is small compared with the maximum communication range the amount of energy radiated vertically downward need not be large

Navigational equipment may need only restricted azimuth cover if, like I L S , they give guidance to a specific point, but area-coverage systems such as Decca, Gee or Loran need omni azimuth coverage Certain position fixing systems such as the A D F sense aerial and the I L S marker require essential downward radiation only

In assessing the performance of an aerial it is usual to measure the field strength at a constant distance from it in three mutually perpendicular planes known as the principal radiation planes These are shown in *Fig 1* The most important one is the azimuth plane and this is only one in which measurements can readily be made on the ground or in the air Measurements in the fore and aft and transverse elevation planes which can be made with scale models are valuable in revealing deficiencies not apparent from azimuth patterns only

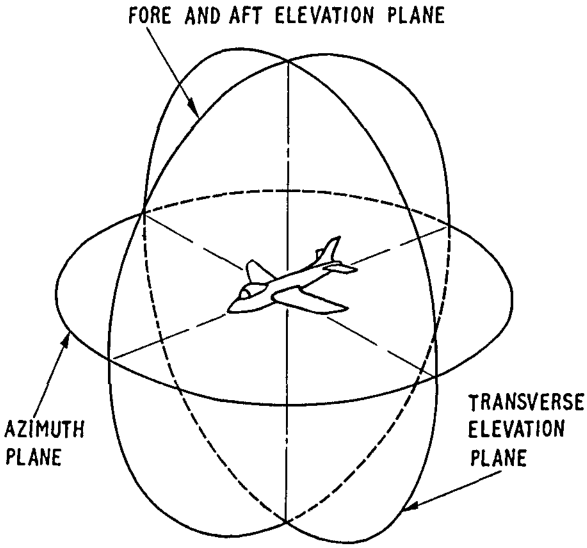

Fig 1 —Principal radiation planes

Gain

Radiation patterns are usually measured in terms of relative field strength To compare one aerial system with another it is necessary to know their relative gains Gain is defined as to the ratio of powers which have to be supplied to an aerial and to a standard reference aerial to produce the same field strength at a fixed distance in a given direction usually that of maximum radiation The practical standard is the half wave dipole

Mechanical Considerations

As well as the electrical criteria discussed above an aircraft aerial must satisfy certain requirements dictated by the operation of the aircraft The most important of these are

(1) Aerodynamic forces , (2) Structural penalties , (3) Climatic conditions

(1) *Aerodynamic Forces*

For the comparatively low speeds of present-day helicopters the lift and drag loadings on aircraft aerials are not large and do not present a real problem Potentially more serious are the effects of vibration, especially at low frequency The author has no information on aerial failures, if any, from this cause and it may be that the dominant resonances are below the range of most aircraft aerials

(2) *Structural Penalties*

Weight is at a premium in helicopters and most aerials, being designed for higher speeds and aerodynamic loads, will appear unduly heavy It is unlikely that special designs can be justified for helicopters, but, it is equally unlikely that internal or suppressed aerials will be used as their installation weight will almost always be very much greater than the equivalent external aerials

(3) *Climatic Conditions*

These will usually be rather less severe than for other aircraft because of the lower operating heights and the only likely cause of trouble may be failures of sealing because of excessive vibration

V H F Aerials

The air-to-ground range at V H F is proportional to the square root of the aircraft height The free space field strength is inversely proportional

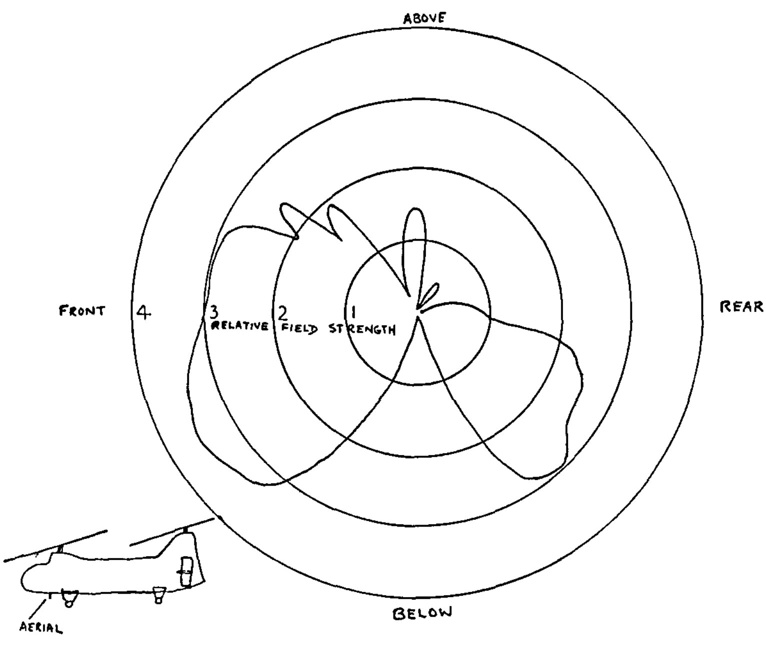

Fig 2—Fore and aft elevation diagram of V H F aerial

to the square of the range and it can, therefore, be shown that for optimum coverage the aircraft aerial must radiate most of its energy in the azimuth plane with a gradual decrease as the angle of depression increases

https://doi.org/10.1017/S2753447200003668 Published online by Cambridge University Press

Fig 2 shows a typical fore and aft elevation polar diagram with the preferred energy distribution This pattern is for an aerial mounted on the underside of an aircraft fuselage and it will be seen that more energy is radiated below the horizontal plane than above The reverse would be true if the aerial were mounted above the fuselage, as the aerial was near the front there is more forward signal above the fuselage than rearward The proportion of energy on the " shadow " side of a conducting surface in the instance of the fuselage decreases as the size of the surface increases in terms of the wavelength Fortunately, at V H F the size of the largest helicopter is still not large in terms of wavelength and adequate coverage is obtainable for aerials mounted above the fuselage

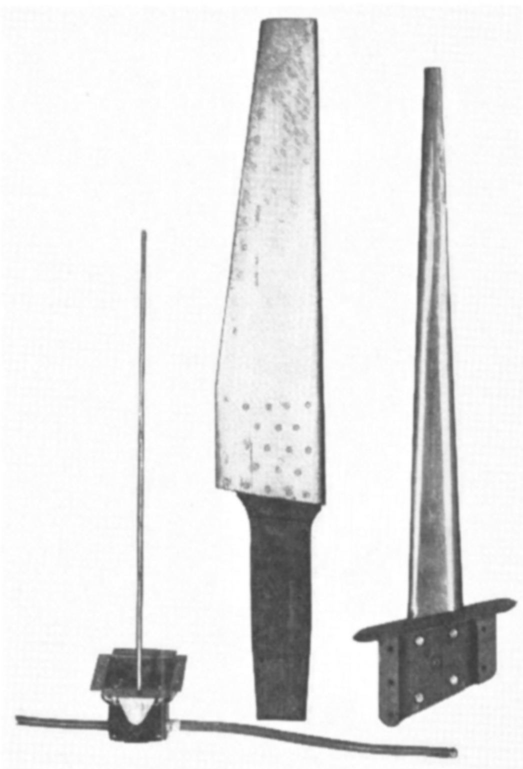

Fig 3—Various V H F aerials

Aerials for V H F communications employ vertical polarization

The direction of polarization for a rod aerial is paralleled to its axis so that V H F aerials must be mounted predominantly vertically

The simplest form of aerial is the half wave dipole This consists of two equal collinear elements which are attached to a transmission line at their adjacent ends The dipole radiates uniformly in all directions in its azimuth plane and is therefore inherently suitable for a communications system The unipole is a derivative in which one half of the dipole is mounted perpendicularly to a conducting plane which produces an electrical image to complete the dipole The radiation characteristics of the unipole are those of the dipole restricted to one hemisphere and its impedance is half of the dipole and is of the order of 30 ohms at resonance

Whilst the simplest form of unipole is the familiar whip aerial approximately a quarter wavelength long, the cross section may be modified as in *Fig* 3 In general an increase in cross section is accompanied by an increase in the useful frequency range An alternative form of unipole is the bent

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Fig 4—Bent sleeve V H F aerials

sleeve aerial shown in *Fig* 4 Its main advantages are vertical height of only 15 inches compared with 22 inches of the whip aerial, wide frequency range, and very robust construction

Aerial Siting

The preferred position for a V H F aerial is centrally above or below

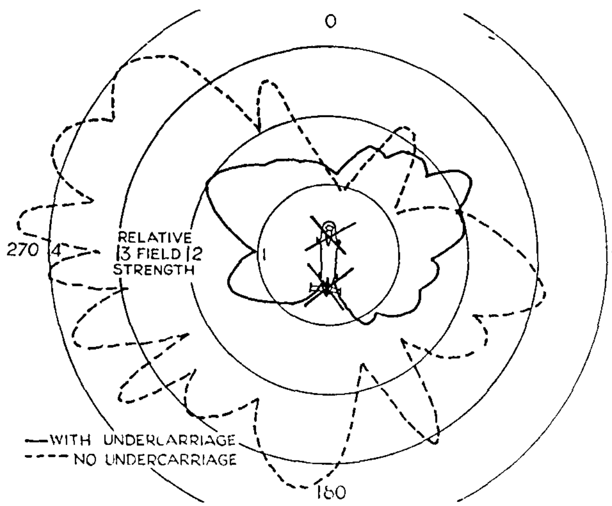

Fig 5—Azimuth radiation patterns of V H F aerial showing effect of obstacles (Block by courtesy of "Aeroplane")

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the fuselage Particularly in helicopters the radiation patterns will be upset by shielding by projecting conducting surfaces Rotor heads, tail fins and external loads are typical examples of these and fixed undercarriages are another hazard *Fig* 5 shows typical azimuth patterns for a V H F aerial on the Bristol type 173 aircraft in which the effect of the undercarriage is shown The two curves are plotted with the same forward signal and the diagram does not show their relative efficiency

The proximity of other aerials may also have an appreciable effect if the aerials show electrical resonance in the operating frequency range

The most difficult type of helicopter is what may be called the " tadpole " shape in which a large forward end with low ground clearance is followed by a thin boom carrying the tail rotor On such a shape the only possible V H F aerial positions appear to be above or below the boom Above the boom there may be shielding by the main rotor head if indeed there is adequate clearance from the blades Below the boom shielding by the main fuselage will be considerable as Fig 6 shows In general the upper positions will be more satisfactory where practicable It should be noted that audio modulation by the rotor blades should not be a serious problem as the modulation frequencies will be below the lower limit of most V H F sets Modulation could be a serious problem on such systems as I L S which rely on the comparison of audio modulated signals, but the application of I L S to helicopters is not likely to be widespread

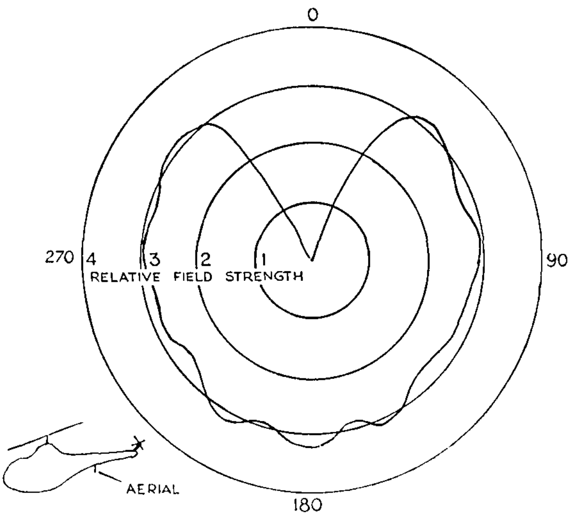

Fig 6 —Azimuth radiation pattern of V H F aerial showing shielding by fuselage (Block by courtesy of " Aeroplane ")

One V H F problem peculiar to helicopters is that the lack of wings leads to azimuth polar diagrams having four main lobes and resembling a four-leaved clover This is particularly noticeable when the fuselage is long compared with its cross-section There does not appear to be a solution with a single aerial

H F Aerials

Because of the range altitude relation for V H F it is necessary to use H F where longer ranges are required It is now generally accepted that radiation from an aircraft H F aerial is determined by the combination of aerial and aircraft structure but the mechanism is not very clearly understood In principle the radiation pattern at a given frequency is determined by the dimensions in terms of wavelength of the major portions of the structure In helicopters the main modes are associated with electrical resonances of the fuselage, *i e*, when this acts as a half wavelength or multiples of this length The aim is therefore to ensure the best transfer of energy from the " aerial " to the airframe over the required frequency band

Transmission to a distant point may be by direct or ground wave or may depend on reflection from the ionosphere For ground wave propagation primarily vertical polarization is required since most ground stations employ vertical aerials For skywave or ionosphere-reflected propagation polarization is less important since changes in polarization occur on reflection For the shorter distances the ground wave is more important and hence it is necessary to obtain the maximum possible proportion of vertically polarized radiation This requires some vertical height in the aerial system which is very difficult to achieve in helicopters having no vertical stabilizing surfaces

It will be seen there are difficulties in providing efficient H F aerials on helicopters This is particularly true at low frequencies on the smaller machines , for example on a 50 ft long aerial the half wave resonance will occur at about 9 Mc/s whereas the H F band begins at between 2 and 3 Mc/s One special problem is in aerial matching since an aerial very short in terms of wavelength has a very low radiation resistance and a very large reactance To match such an aerial requires networks in which the power dissipated may be as great or greater than the power radiated by the aerial In general the best that can be achieved with H F aerials is to make them as long as possible and as far off the fuselage as practicable

A D F

Since the problems of A D F are being covered by another speaker the subject will only be briefly considered here The main problems are in siting the loop aerial to reduce quadrantal error to a minimum and in siting the sense aerial to obtain a balanced cone-of-silence The generally preferred regions for both aerials are near the electrical centre of the fuselage, which probably coincides with the geometrical centre for uniform fuselages but may be more difficult to determine on the " tadpole " type

DECCA

At the very low operating frequencies of this equipment aerial efficiencies are very low Considerable care must be taken to minimize aerial loss by proper choice of insulating materials and the form of the radiator It is usual to attach an amplifier valve as close as possible to the aerial In this way losses due to matching networks are avoided

The type of aerial which has been used successfully in a capacity plate mounted close to the fuselage It is important to site the aerial to minimize static pick-up which will otherwise limit the signal-to-noise ratio obtainable

CONCLUSION

Of necessity this paper can only deal very sketchily with the question of helicopter aerials It is hoped, however, that some of the basic problems have been covered