No. 60

THE MARCONI REVIEW

May-June, 1936

G. Marconi

CONTENTS

MARCONI'S WIRELESS TELEGRAPH COMPANY LTD.
Electra House, Victoria Embankment, London, W.C. 2

THE MARCONI REVIEW

No. 60. *May-June, 1936.*

Editor: H. M. DOWSETT, M.I.E.E., F.Inst.P.
Assistant Editor: L. E. Q. WALKER, A.R.C.S.

THE EFFECT OF AIRCRAFT DESIGN UPON THAT OF AIRCRAFT RADIO EQUIPMENT

In the normal way a radio engineer who has to guarantee the performance of his equipment is entitled to select or reject the site on which the apparatus is to be installed. In the aircraft world, however, and to a less extent in the marine world, no such discrimination is possible—the site is provided and the apparatus has to be made to function as well as possible under the conditions which obtain. Furthermore, the aircraft radio manufacturer is usually not in a position to insist upon improvements being effected to the site provided, and is, therefore, greatly in the hands of the aircraft manufacturer for the efficient or inefficient working of his equipment.

The aim of this article is, accordingly, to draw the attention of the aeronautical world to this insufficiently recognised fact and to press for a much greater degree of co-operation between the manufacturers of aircraft and of aircraft radio equipment than is the case at present.

IT is by now generally realised that radio equipment is one of the most important, if not, indeed, the most important part of the auxiliary equipment of an aircraft since, without means of communication with a land or marine base, the functions of a military, naval or civil aircraft cannot be effectively performed.

A matter of prime importance in radio engineering is that of the situation selected for the installation of the equipment, since the performance of the most efficient apparatus may be rendered practically null and void if it is installed on an unsatisfactory site. The main requirements in this respect lie in providing an efficient aerial system and proper accommodation for the equipment so that it may be free of external " background " noise and the minimum of electrical interference from outside sources, and in ensuring an adequate power supply.

Looked at from this point of view, therefore, an aircraft in which radio equipment is to be installed can be considered purely as a " site " for the equipment, and the considerations which apply in connection with a land or marine site are, in general, applicable in the case of the aircraft site. On this basis the aircraft can, in the majority of cases, hardly be considered as an ideal " site." There is no doubt, however, that if the aircraft is properly prepared for the installation of radio equipment remarkably efficient results may be obtained.

From the above considerations it will be clear that the aircraft radio manufacturer is to a large extent dependent for the satisfactory performance of his equipment on the conditions provided by the aircraft manufacturer. There is, accordingly, no doubt that close co-operation between the aircraft and aero engine manufacturer on the one hand and the aircraft radio manufacturer on the other is very necessary and can only be beneficial to all parties concerned.

In order briefly to outline the aspects of this matter on which such co-operation is desirable, it is proposed to discuss the main individual items of an aircraft radio installation and the considerations involved in each case. These main items of an installation are as follows :—

Aerial system,
Power supply,
Transmitter,
Receiver.

Aerial System.

A radio aerial system comprises fundamentally either an open aerial with counter-poise or a closed loop. The former is an efficient radiator or collector of energy, and is used both for transmission and reception purposes, while the latter is relatively inefficient, but possesses more highly marked directive properties. It is, accordingly, normally used for directional reception purposes alone.

The maximum range obtainable from any radio equipment depends, other factors being equal, upon the efficiency of the aerial system used. In an aircraft the complete open aerial system normally consists of a wire insulated from the structure of the aircraft and a mass earth or counterpoise ; the efficiency of such an aerial system depends primarily upon the " effective height " of the aerial wire. To obtain efficiency it is necessary, therefore, particularly where transmission has to be effected that the aerial wire should have as great an " effective height " as possible, which inevitably necessitates that it should be external to the structure of the aircraft, even though it is fully realised that such an arrangement is bound to cause some slight reduction in the performance of the aircraft due to " drag."

The various types of open and closed aerial systems which are normally employed on aircraft are as follows :—

(A) *Trailing Aerials.* The use of this type of aerial is essential for efficient transmission or reception on medium wavelengths, i.e., those wavelengths normally used in commercial air line work. A trailing aerial usually comprises a 200 ft. length of stranded wire (phosphor bronze is employed by the Marconi Company) kept taut in flight by means of a bead type weight at its far end, the wire being accommodated on an insulated aerial winch when not in use, and passing through the skin of the aircraft by means of an insulated tube, the fairlead—or in the case of flying boats, the hull insulator.

Normally the head of the fairlead is arranged in close proximity to the winch, the position for the latter being governed by considerations of ease of operation by that number of the crew responsible for letting out and winding in the aerial. Other considerations affecting the length and direction of the fairlead itself are the need for ensuring that the aerial wire cannot foul either the propellors, the generator windmill or the structure of the aircraft during normal evolutions or in " bumps," also the necessity for the fairlead to avoid controls, etc., in its run.

A point of interest arises in the case of trailing aerials, namely, that with the steady increase in speed of modern aircraft, the effective height is tending to decrease, in spite of the general increase in power of aircraft transmitters which is now available as a result of the improved power-to-weight ratio brought about by more modern methods of design. The problem of overcoming this difficulty has now to be faced, particularly where reception of signals from the aircraft has to be effected on a direction receiver such as the Marconi-Adcock.

One line of attack will possibly lie along the lines of using some form of paravane arranged part way along the length of the wire so as to ensure that the aerial drops more or less vertically below the aircraft from a certain distance before streaming out horizontally.

Another possibility lies in the use of steel aerial wire of small cross section, together with a heavier aerial weight than is employed at present.

One arrangement of trailing aerial system, favoured in certain countries as reducing " drag," lies in leading out the aerial from the tail of the aircraft. This method has the disadvantage that a remotely-controlled winch is needed with increased weight and cost. Apart from this, capacity losses in the lead from the fairlead to the transmitter tend to become series unless the transmitter were also installed near the tail and were capable of being completely remotely controlled from the front of the fuselage.

The existing European (medium-wave) radio organisation for commercial aircraft is already sufficiently complex (involving the use of different wavelengths in different areas and for different purposes) to make *full* remote control of the transmitter a difficult problem to solve ; as it is steadily increasing in complexity, the possibility of employing this type of aerial system in Europe does not appear too hopeful, but some such arrangement may eventually have to be developed in view of the increasing importance of " drag " to designers of high-speed modern aircraft.

(B) *Fixed Aerials.* This type of aerial comprises, as its name implies, a wire or wires rigidly attached to but insulated from the structure of the aircraft.

It is used for medium wave working on commercial aircraft for two-way communication at close ranges, but is inefficient as a radiator and, to a less degree, as a collector on these wavelengths, owing to its small physical dimensions, compared with the wavelengths used.

This type of aerial becomes more efficient on intermediate or short wavelengths and since there is no danger of the wire fouling controls, etc., during aerobatics (such as would occur with a trailing aerial) is much used on military and naval aircraft.

The actual form of fixed aerial used depends upon the design of the aircraft to which it is to be fitted, some of the considerations involved being the necessity for obtaining the greatest possible " effective height " above mass earth without impairing too seriously the performance of the aircraft, the need for ensuring that the aerial is as non-directional as possible (this being a problem more experienced on the shorter wavelengths), and the necessity for ensuring that the aerial does not form a dangerous commercial aircraft—nor reduce the effective field of fire for machine guns or impeded parachute exit in the case of military or naval aircraft.

(C) *Loop Aerials.* This type of (closed) aerial is used for directional reception purposes only. The efficiency of a receiving system employing a loop aerial depends upon (A) the electrical area turns of the loop ; (B) the site selected for the loop ; (C) whether the loop is of the screened or unscreened type and (D) the sensitivity of the receiver used. Screened loops have the advantage over the unscreened type in that quadrantal error is reduced and at the same time mechanical robustness (necessary when the loop is mounted externally on the aircraft) is automatically provided ; on the other hand their " pick up " is less than in the case of unscreened loops, and hence for a given range under given conditions a receiver of increased sensitivity is required.

Either fixed or rotatable loop aerials are employed according to the system of D.F. in use ; fixed loops of the unscreened type are usually employed in wooden or composite aircraft having a wooden or fabric covering, and are built-in in the form of wing or fuselage loops. If the aircraft is of all metal construction, with a metal skin, then a screened loop mounted externally to the fuselage is used. Rotating loops, which are invariably of the screened type, are usually mounted externally, primarily due to considerations of space.

(D) *Earth System.* This is provided by " bonding " together all metal parts of the aircraft, so that they are at the same electrical potential in order to form the counterpoise for the fixed or trailing aerial. It is also necessary that this work should be carried out in the first instance, and subsequently maintained, in an extremely careful and thorough manner, on account of the following considerations :—

(1) Induced potentials may be set up in any unbonded portions during transmission, the potentials often being of a sufficiently high value to cause a spark-over with the consequent risk of fire.

(2) Variation in the capacity of the aerial system may occur with defective bonding, with the result that (A) the transmission wavelength may vary in the case of self oscillator type transmitters ; (B) dangerously high feed currents may occur in the case of master oscillator type transmitters and hence cause fuses to " blow " ; (C) in either case, transmission and reception may be caused to be intermittent ; (D) difficulties may be experienced in receiver tuning and (E) reception may become noisy due to what amounts to " chattering " contacts in the aerial circuit.

(3) Sparking, the consequent risk of fire, may occur between an unbonded piece of metalwork and the remainder, in the event of an electrical charge being set up in the " earth " system.

The extent of the bonding carried out in any particular case depends to a certain extent upon the wavelengths to be used—the shorter the wavelength the more care must be taken to ensure that all metallic portions are brought into bond. Bonding must, therefore, be well carried out in the first instance, suitable manufacturing methods must be employed and subsequent maintenance must be regularly and meticulously effected. These are points on which the aircraft manufacturer can be of the utmost assistance to the aircraft radio manufacturer, both in ensuring an efficient bonding system during construction of the aircraft and also in providing easy means of access to the main junction points, etc., for subsequent inspection and maintenance.

Any aircraft which is at all likely to be fitted with wireless equipment should automatically be bonded during construction, even though this entails a slight increase in first cost, as bonding subsequent to manufacture is always a costly and difficult proceeding and, in fact, can never be really efficiently carried out except possibly during Certificate of Airworthiness overhauls.

(E) *Dangers Due to Static Discharges.* The amount of authentic information available on this subject is still comparatively meagre, but the following appear to be the main likely categories of risks which arise, together with means for their reduction or elimination :—

(i) The presence of an aircraft in the path of a lightning flash. In this case it would appear to make no difference whether the trailing aerial was wound in or not, the whole matter being one of pure chance. The odds are, of course, very strongly against such an occurrence, in fact, there is no recorded instance within the writer's knowledge.

(ii) The presence of an aircraft within areas of high potential. This is a state of affairs that is, or may be unless special precautions are taken, relatively common, and there is no doubt that the existence of a long trailing conductor in an area of high electric strain may lower the resistance of the potential break-down path to such an extent as to " trigger " a discharge, which, of course, will pass via the trailing aerial and the aircraft. A number of cases are on record from which all available evidence goes to show that this is, in effect, what has occurred ; in such cases the aerial has invariably been fused-off and lost, and varying amount of damage done inside the fuselage. So far as is known, however, no loss of life has occurred in a British commercial aircraft due to this cause.

(iii) The only certain remedies against this type of risk are (A) to avoid certain classes of cloud formation which are notoriously dangerous in this respect and (B) to wind in the trailing aerial *at once* whenever any indications whatsoever are obtained that the aircraft is flying in an area of high potentials.

(iv) The building-up of a charge on the aircraft itself due either to induction or to flying through charged rain, snow, etc. (particularly snow). This risk is appreciable only on aircraft which has a large metal area and hence can have a larger charge induced into, or built up on to, them. The charge may either be dissipated gradually during flight in the form of brushing from sharp points on the structure, or may possibly travel via the trailing aerial, if unwound, to a point of opposite polarity on the ground or in a cloud, or may not be dissipated at all (if the potential is low) until the aircraft reaches the ground or water. In such latter cases, the means of discharge is automatically provided in the case

(C) *Loop Aerials.* This type of (closed) aerial is used for directional reception purposes only. The efficiency of a receiving system employing a loop aerial depends upon (A) the electrical area turns of the loop; (B) the site selected for the loop; (C) whether the loop is of the screened or unscreened type and (D) the sensitivity of the receiver used. Screened loops have the advantage over the unscreened type in that quadrantal error is reduced and at the same time mechanical robustness (necessary when the loop is mounted externally on the aircraft) is automatically provided; on the other hand their "pick up" is less than in the case of unscreened loops, and hence for a given range under given conditions a receiver of increased sensitivity is required.

Either fixed or rotatable loop aerials are employed according to the system of D.F. in use; fixed loops of the unscreened type are usually employed in wooden or composite aircraft having a wooden or fabric covering, and are built-in in the form of wing or fuselage loops. If the aircraft is of all metal construction, with a metal skin, then a screened loop mounted externally to the fuselage is used. Rotating loops, which are invariably of the screened type, are usually mounted externally, primarily due to considerations of space.

(D) *Earth System.* This is provided by "bonding" together all metal parts of the aircraft, so that they are at the same electrical potential in order to form the counterpoise for the fixed or trailing aerial. It is also necessary that this work should be carried out in the first instance, and subsequently maintained, in an extremely careful and thorough manner, on account of the following considerations:—

(1) Induced potentials may be set up in any unbonded portions during transmission, the potentials often being of a sufficiently high value to cause a spark-over with the consequent risk of fire.

(2) Variation in the capacity of the aerial system may occur with defective bonding, with the result that (A) the transmission wavelength may vary in the case of self oscillator type transmitters; (B) dangerously high feed currents may occur in the case of master oscillator type transmitters and hence cause fuses to "blow"; (C) in either case, transmission and reception may be caused to be intermittent; (D) difficulties may be experienced in receiver tuning and (E) reception may become noisy due to what amounts to "chattering" contacts in the aerial circuit.

(3) Sparking, the consequent risk of fire, may occur between an unbonded piece of metalwork and the remainder, in the event of an electrical charge being set up in the "earth" system.

The extent of the bonding carried out in any particular case depends to a certain extent upon the wavelengths to be used—the shorter the wavelength the more care must be taken to ensure that all metallic portions are brought into bond. Bonding must, therefore, be well carried out in the first instance, suitable manufacturing methods must be employed and subsequent maintenance must be regularly and meticulously effected. These are points on which the aircraft manufacturer can be of the utmost assistance to the aircraft radio manufacturer, both in ensuring an efficient bonding system during construction of the aircraft and also in providing easy means of access to the main junction points, etc., for subsequent inspection and maintenance.

Any aircraft which is at all likely to be fitted with wireless equipment should automatically be bonded during construction, even though this entails a slight increase in first cost, as bonding subsequent to manufacture is always a costly and difficult proceeding and, in fact, can never be really efficiently carried out except possibly during Certificate of Airworthiness overhauls.

(E) *Dangers Due to Static Discharges.* The amount of authentic information available on this subject is still comparatively meagre, but the following appear to be the main likely categories of risks which arise, together with means for their reduction or elimination :—

(i) The presence of an aircraft in the path of a lightning flash. In this case it would appear to make no difference whether the trailing aerial was wound in or not, the whole matter being one of pure chance. The odds are, of course, very strongly against such an occurrence, in fact, there is no recorded instance within the writer's knowledge.

(ii) The presence of an aircraft within areas of high potential. This is a state of affairs that is, or may be unless special precautions are taken, relatively common, and there is no doubt that the existence of a long trailing conductor in an area of high electric strain may lower the resistance of the potential break-down path to such an extent as to " trigger " a discharge, which, of course, will pass via the trailing aerial and the aircraft. A number of cases are on record from which all available evidence goes to show that this is, in effect, what has occurred ; in such cases the aerial has invariably been fused-off and lost, and varying amount of damage done inside the fuselage. So far as is known, however, no loss of life has occurred in a British commercial aircraft due to this cause.

(iii) The only certain remedies against this type of risk are (A) to avoid certain classes of cloud formation which are notoriously dangerous in this respect and (B) to wind in the trailing aerial *at once* whenever any indications whatsoever are obtained that the aircraft is flying in an area of high potentials.

(iv) The building-up of a charge on the aircraft itself due either to induction or to flying through charged rain, snow, etc. (particularly snow). This risk is appreciable only on aircraft which has a large metal area and hence can have a larger charge induced into, or built up on to, them. The charge may either be dissipated gradually during flight in the form of brushing from sharp points on the structure, or may possibly travel via the trailing aerial, if unwound, to a point of opposite polarity on the ground or in a cloud, or may not be dissipated at all (if the potential is low) until the aircraft reaches the ground or water. In such latter cases, the means of discharge is automatically provided in the case of flying boats or seaplanes (via the metal hull or floats), but in the case of land craft with tail wheel instead of tail skid, arrangements should be made to provide either an earthing chain which touches the ground and hence allows the charge to be dissipated as soon as the aircraft lands, or an " Ecta " or similar type of tail wheel to serve the same purpose.

Power Supply.

The amount of power required to operate an aircraft radio installation depends upon whether combined transmitter-receiving equipment is carried (and if so the power rating of the transmitter), or receiving equipment alone. In the former case the maximum power requirements may be as high as $\frac{1}{2}$ kw., while in the latter a few watts will suffice.

Except in the case of receivers (and certain extremely low-power short wave transmitters) it is not practicable to store in the aircraft, and expend in flight, sufficient energy to operate the equipment over a period corresponding to the endurance of the aircraft. Power has, therefore, to be obtained either by coupling a generator mechanically to the engine, or by a windmill-driven generator.

Three alternative methods are available with practically all Marconi aircraft radio equipments for providing the necessary H.T. and L.T. supplies. In the first, a wind driven generator (with constant-speed windmill) provides H.T. and L.T. D.C. supply for both transmitter and receiver valve anodes and filaments, an accumulator being floated across the generator L.T. output in order to smooth out commutator ripple and maintain the supply voltage at a steady value, and to permit of short-period reduced-power ground testing of the installation. This latter is of invaluable assistance for maintenance purposes.

In the second alternative a wind driven generator (also with constant-speed windmill) provides H.T. and L.T. D.C. supply as before, but is arranged to have an L.T. output well in excess of wireless requirements, this excess being available for other electrical services on the aircraft.

With this system short-period reduced-power ground testing of the radio installation is possible, and, in addition, continuous full-power emergency communication is rendered available, provided that a small petrol engine and flexible drive can be carried on the aircraft (the flexible drive is, of course, connected to the generator shaft in place of the windmill under such conditions).

The third alternative is used only when a suitable L.T. supply system (comprising wind or engine driven generator, switchboard, accumulator, etc.) is already available as part of the standard equipment on the aircraft, and comprises a rotary transformer for transmitter valve anode supply and an anode converter for receiver valve anodes, both these small motor generators being operated off the L.T. supply system. With this method full-power short-period ground testing of the radio installation is possible and—assuming that the L.T. generator is wind—and not engine—driven and that the petrol engine and flexible drive referred to above is carried—full-power emergency communication can be effected over an indefinite period.

Up to the present it has not been possible in this country to progress very far with the development of engine-driven double output (H.T. and L.T.) generators, due partly to lack of standardisation on the part of aero engine manufacturers of suitable generator couplings and partly to difficulties in providing a means of ensuring a steady speed for the generator, i.e., a steady output voltage, irrespective of the r.p.m. of the engine. Where one is dealing with electrical services operated at a low voltage, and with an accumulator provided as a " buffer " between the generator and the load, the permissible tolerances of generator speed are fairly wide and the varying r.p.m. of the engine-driven generator does not present any difficulty ; radio apparatus on the other hand demands a power supply of correct and constant voltage (particularly where anode supplies are concerned) if the apparatus is to function satisfactorily, and the tolerances permitted are very narrow.

Hence engine-driven generators as at present available in this country are of the single output L.T. type, and in such cases, of course, H.T. power supply for the wireless apparatus is obtained from rotary transformers, while the supply voltage needed for the wireless valve filaments is arranged to be identical with that of the L.T. system.

Transmitter.

Apart from points of pure design there are two main considerations affecting the installation of radio transmitters in which the aircraft manufacturer is involved. The first is the provision of proper accommodation for the transmitter ; while it is fully well realised that this is a matter which is often unattainable in practice, the provision of accommodation for the transmitter so that it may be hand-operated, and so avoid the cost and weight of remote controls, is eminently desirable, particularly since the obligatory use of remote controls necessarily imposes limitations upon the ease and flexibility of operation of the transmitter.

The second consideration is that of noise level in the aircraft. Troubles due to high noise level are more often experienced with high-performance open-cockpit military or naval aircraft than with enclosed type commercial aircraft. With open-cockpit aircraft the only lines along which improvements can be effected lie in the use of mask or laryngaphone microphones, in silencing the exhaust noise as much as practicable, and by the reduction of propellor noise by using geared engines or a different type of propellor ; in enclosed type commercial aircraft an improvement can often be effected by sound-proofing the cabin and cockpit walls.

Receiver.

It is very desirable—and even essential, in the case of a short-wave receiver where extreme delicacy of adjustment may be required—that an aircraft receiver should be installed in such a position that that member of the crew who will be operating it can have it under his direct control in some convenient place in front of him rather than having to operate it by remote controls. Now that it has been found possible, with improved methods of design, to produce receivers of considerably smaller dimensions than hitherto, there should be no real difficulty in allowing, in the design of new aircraft, sufficient space for the accommodation of the receiver in a position convenient for hand operation, and this would undoubtedly result in a neater and more convenient method of installing and operating this item.

Apart from the above considerations, the average aircraft is a particularly unsatisfactory site in which to install a radio receiver due (A) to the high noise level and (B) to the high level of electrical interference often experienced.

of flying boats or seaplanes (via the metal hull or floats), but in the case of land craft with tail wheel instead of tail skid, arrangements should be made to provide either an earthing chain which touches the ground and hence allows the charge to be dissipated as soon as the aircraft lands, or an " Ecta " or similar type of tail wheel to serve the same purpose.

Power Supply.

The amount of power required to operate an aircraft radio installation depends upon whether combined transmitter-receiving equipment is carried (and if so the power rating of the transmitter), or receiving equipment alone. In the former case the maximum power requirements may be as high as $\frac{1}{2}$ kw., while in the latter a few watts will suffice.

Except in the case of receivers (and certain extremely low-power short wave transmitters) it is not practicable to store in the aircraft, and expend in flight, sufficient energy to operate the equipment over a period corresponding to the endurance of the aircraft. Power has, therefore, to be obtained either by coupling a generator mechanically to the engine, or by a windmill-driven generator.

Three alternative methods are available with practically all Marconi aircraft radio equipments for providing the necessary H.T. and L.T. supplies. In the first, a wind driven generator (with constant-speed windmill) provides H.T. and L.T. D.C. supply for both transmitter and receiver valve anodes and filaments, an accumulator being floated across the generator L.T. output in order to smooth out commutator ripple and maintain the supply voltage at a steady value, and to permit of short-period reduced-power ground testing of the installation. This latter is of invaluable assistance for maintenance purposes.

In the second alternative a wind driven generator (also with constant-speed windmill) provides H.T. and L.T. D.C. supply as before, but is arranged to have an L.T. output well in excess of wireless requirements, this excess being available for other electrical services on the aircraft.

With this system short-period reduced-power ground testing of the radio installation is possible, and, in addition, continuous full-power emergency communication is rendered available, provided that a small petrol engine and flexible drive can be carried on the aircraft (the flexible drive is, of course, connected to the generator shaft in place of the windmill under such conditions).

The third alternative is used only when a suitable L.T. supply system (comprising wind or engine driven generator, switchboard, accumulator, etc.) is already available as part of the standard equipment on the aircraft, and comprises a rotary transformer for transmitter valve anode supply and an anode converter for receiver valve anodes, both these small motor generators being operated off the L.T. supply system. With this method full-power short-period ground testing of the radio installation is possible and—assuming that the L.T. generator is wind—and not engine—driven and that the petrol engine and flexible drive referred to above is carried—full-power emergency communication can be effected over an indefinite period.

Up to the present it has not been possible in this country to progress very far with the development of engine-driven double output (H.T. and L.T.) generators, due partly to lack of standardisation on the part of aero engine manufacturers of suitable generator couplings and partly to difficulties in providing a means of ensuring a steady speed for the generator, i.e., a steady output voltage, irrespective of the r.p.m. of the engine. Where one is dealing with electrical services operated at a low voltage, and with an accumulator provided as a " buffer " between the generator and the load, the permissible tolerances of generator speed are fairly wide and the varying r.p.m. of the engine-driven generator does not present any difficulty ; radio apparatus on the other hand demands a power supply of correct and constant voltage (particularly where anode supplies are concerned) if the apparatus is to function satisfactorily, and the tolerances permitted are very narrow.

Hence engine-driven generators as at present available in this country are of the single output L.T. type, and in such cases, of course, H.T. power supply for the wireless apparatus is obtained from rotary transformers, while the supply voltage needed for the wireless valve filaments is arranged to be identical with that of the L.T. system.

Transmitter.

Apart from points of pure design there are two main considerations affecting the installation of radio transmitters in which the aircraft manufacturer is involved. The first is the provision of proper accommodation for the transmitter ; while it is fully well realised that this is a matter which is often unattainable in practice, the provision of accommodation for the transmitter so that it may be hand-operated, and so avoid the cost and weight of remote controls, is eminently desirable, particularly since the obligatory use of remote controls necessarily imposes limitations upon the ease and flexibility of operation of the transmitter.

The second consideration is that of noise level in the aircraft. Troubles due to high noise level are more often experienced with high-performance open-cockpit military or naval aircraft than with enclosed type commercial aircraft. With open-cockpit aircraft the only lines along which improvements can be effected lie in the use of mask or laryngaphone microphones, in silencing the exhaust noise as much as practicable, and by the reduction of propellor noise by using geared engines or a different type of propellor ; in enclosed type commercial aircraft an improvement can often be effected by sound-proofing the cabin and cockpit walls.

Receiver.

It is very desirable—and even essential, in the case of a short-wave receiver where extreme delicacy of adjustment may be required—that an aircraft receiver should be installed in such a position that that member of the crew who will be operating it can have it under his direct control in some convenient place in front of him rather than having to operate it by remote controls. Now that it has been found possible, with improved methods of design, to produce receivers of considerably smaller dimensions than hitherto, there should be no real difficulty in allowing, in the design of new aircraft, sufficient space for the accommodation of the receiver in a position convenient for hand operation, and this would undoubtedly result in a neater and more convenient method of installing and operating this item.

Apart from the above considerations, the average aircraft is a particularly unsatisfactory site in which to install a radio receiver due (A) to the high noise level and (B) to the high level of electrical interference often experienced.

The considerations which apply in the case of high noise level and the means of combating the difficulties experienced are similar to those which apply in the case of transmitters (namely, reduction of exhaust and propellor noise) ; in addition, the use of a well-fitting helmet, with properly designed pockets to take the telephone earpieces will greatly improve matters.

With regard to electrical interference, this is normally due to three main causes, namely, interference from engine ignition system, interference from electrical circuits other than the ignition system and interference caused by defective bonding (which latter has already been referred to earlier in this paper). The extent of the electrical interference experienced on an average type of aircraft is still extremely high, and this has greatly militated against the use of highly sensitive receivers such as those of the superheterodyne class, since such receivers can be used only where electrical background noise level is low. In the past, therefore, the policy of the Marconi Company with regard to aircraft receiver design has necessarily had to be governed by these purely practical considerations, with the result that the sensitivity of the receiver has had to be kept lower than is desirable in view of the limitations of site provided by the aircraft manufacturers. As site conditions improve, i.e., as aircraft are manufactured in a more completely prepared state for the installation of receiving equipment, so will the general use of more highly sensitive receivers become possible.

With regard to interference from the engine ignition system, the *only* known and proved cure for this trouble consists in enclosing the major components in an earthed metallic covering, i.e., "screening." Experience is the only guide in forecasting what steps are likely to be required in this respect, but the main factors governing the matter are as follows :—

(A) The wavelength used.
(B) The sensitivity of the receiver.
(C) The inherent screening introduced by the design of the aircraft.
(D) The natural screening provided by engine cowlings.
(E) The disposition of the engines relative to the receiver and aerial.

Screening of ignition systems can be considered under three distinct stages, their successive application being dependent upon the severity of the interference experienced.

These stages are as follows :—

(A) The supply of screened L.T. leads between magnetos and switches, including screened contact breaker covers, switches, terminal blocks at wing roots, etc.
(B) The provision of screened magnetos, distributors and H.T. leads.
(C) The provision of screened plugs.

With the present design of Marconi medium wave aircraft receivers (A) alone usually suffices, it being sometimes necessary to apply stage ; (B) to one or more engines in particularly bad cases or where extra H.F. amplification is used in the receiver for D.F. purposes. On intermediate or short wavelengths, stages (A) and (B) are almost invariably needed, stage (C) often being desirable, in addition ; while on ultra short wavelengths, all three stages have to be applied.

The extent of interference from electrical circuits other than the ignition system depends upon the sensitivity of the receiver used, the wavelengths employed and the proximity of the receiver and aerial to the source of interference. Reduction of such interference depends upon individual cases and usually involves the use of suitably earthed combinations of condensers and chokes across the output of electrical generators, the use of H.F. chokes in certain leads, the use of screened leads and components in the electrical circuits, and the careful maintenance of commutators, etc., to ensure that they are sparkless in action.

Conclusions.

From what has been written it is obvious that a wide field exists for co-operation between the aircraft manufacturer and the aircraft radio manufacturer, in order that aircraft design may, at any rate, not militate against efficient design of aircraft radio equipment and accessories. The Marconi Company has had more years of experience on this class of work than any other aircraft radio manufacturer, on all types of aircraft and has naturally acquired a wealth of accumulated data in the process ; in addition, it keeps fully in touch with the trend of aircraft design as exemplified by the latest products, and will be glad at any time to co-operate with and assist the aircraft manufacturer with regard to any radio problem. Such co-operation can have only beneficial results to all parties concerned, namely, cheaper, lighter and more efficient radio equipment, simpler and less costly installation and improved sales not only of radio equipment, but even of the aircraft themselves.

C. B. Carr.

FIELD STRENGTHS REQUIRED FOR COMMERCIAL TELEGRAPHY ON SHORT WAVES

This article, prepared by the Engineering Department of Cable and Wireless, consists of a compilation of data regarding field strengths required for commercial radio services and should prove most useful in obtaining a more complete knowledge of the principles affecting short wave communication.

It is pointed out that, whilst field strengths can be computed for any route and distance, the deciding factor is the noise level at the receiving end, and that therefore before this is known, no accurate predications can be made regarding the commercial value of such field strengths.

General Considerations affecting Short-Wave Communication.

IN order to effect efficient communication by short-wave wireless, the following factors are of major importance :—

(A) The selection of a suitable wavelength, in accordance with the season, time of day and geographical disposition of the Transmitter and Receiver ;

and (B) The production of the necessary field strength at the receiving station to ensure the satisfactory operation of its apparatus.

With regard to (A) above, the behaviour of wavelengths between 14 and 100 metres is now fairly well known, and no difficulty arises in the choice of wavelength, except in the case of some long distance circuits having diverse wavelength requirements at each end of the circuit during particular seasons and times of day.

Limitations Imposed by Receiver Noise.

With regard to (B) above, the field strength required, in the absence of atmospheric noise, must be such as to overcome the noise level of the receiver. With modern Commercial Receivers this necessitates approximate minimum field strengths referred to a $\frac{1}{2}\lambda$ vertical aerial as under :—

On 15 metres	0.5 micro-volts per metre
On 25 metres	0.2 ,, ,, ,,
On 40/100 metres less than	0.2 ,, ,, ,,

The attenuation factors for various ionic densities and wavelengths* enable hourly average field strengths obtainable from any given transmitter to be predicted with reasonable accuracy, at least for transmission over daylight zones.

Conditions at night, however, particularly over zones of extreme darkness, are frequently much more variable, and field strengths become less amenable to calculation.

Average hourly values of peak field strengths measured at Ascension from frequency modulated telegraph transmitters situated near London are shown in Figs. 1 and 2.

---

* Refer to Eckersley and Tremellen, MARCONI REVIEW, No. 17, February 1930, and to Eckersley, MARCONI REVIEW, No. 30, May/June 1931.

Limitations Imposed by External Noise.

In general, however, the minimum field strength requirements are dependent almost entirely on the prevailing atmospheric noise-level. In order, therefore, to

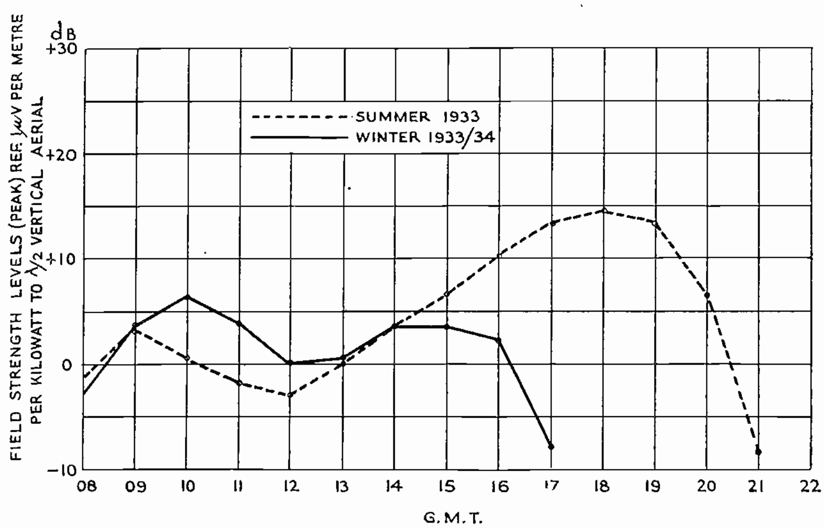


FIG. I. *Field strength at ascension of* 16 *m. signals from London.*

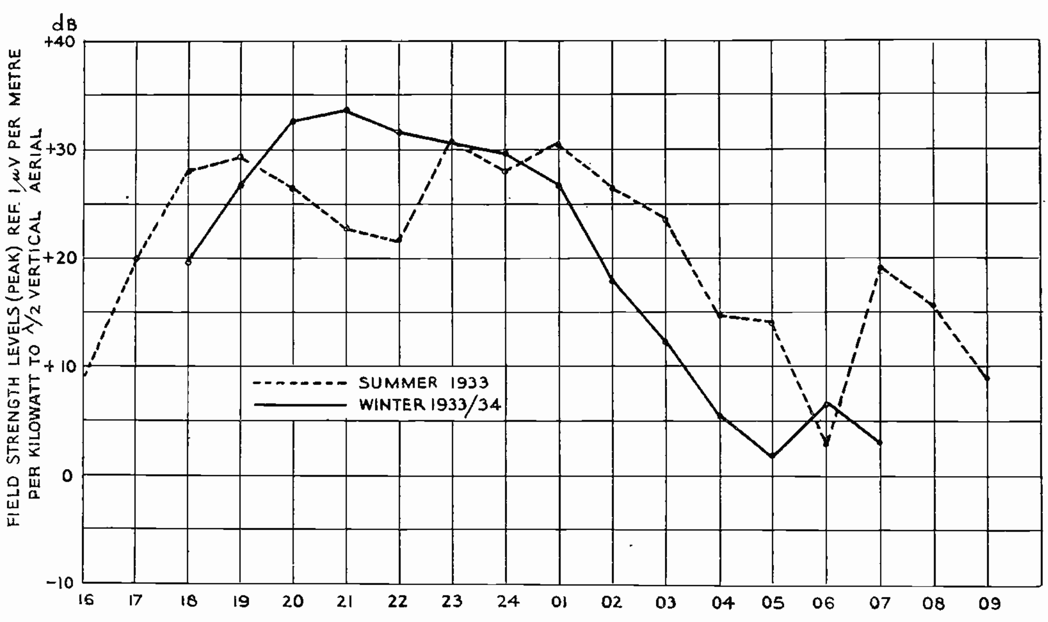


FIG. 2. *Field strength at ascension of* 32 *m. signals from London.*

predict the performance of a circuit equipped with modern transmitters, receivers and directive aerials of known performance, it is essential first to make a preliminary study of the degree and geographical distribution of atmospherics which produce disturbances at the receiver. For there may be one predominating source of disturbance so located with respect to the line of communication that little, if any,

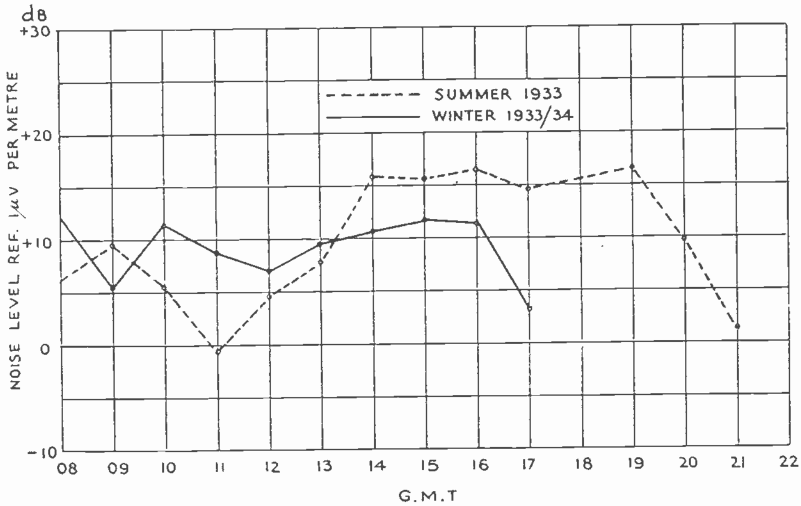


FIG. 3. *Ascension noise level, 16 m.*

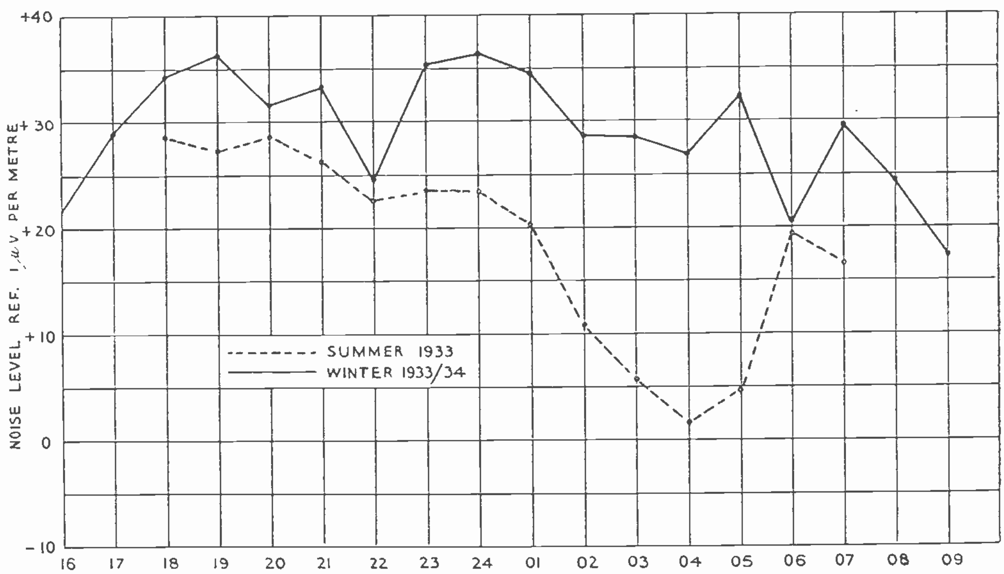


FIG. 4. *Ascension noise level, 32 m.*

increase of Signal/Noise ratio will accrue from the use of directive aerials at the receiving station.

One method of determining the degree of disturbance is to correlate the field strength and the ratio of minimum signal to maximum noise (hereafter termed the

Figure-of-merit) as obtained on a receiver fed from a λ/2 vertical aerial, the output being arranged to operate a tape recorder. If the field strength measurements refer to peak values, the fading ratio must be taken into account. This latter ratio is of the order of 20/22 dB. for Continuous Waves, and 10/12 dB. for Frequency (or Amplitude) Modulated Waves.

Receiving Aerial.	λ (m.).	Period.	Signal Gain (dB) over λ/2 vertical aerial.		Signal-Noise Gain (dB) over λ/2 vertical aerial.	
			Ascension.	Sierra Leone.	Ascension.	Sierra Leone.
A	16	Summer, 1934	14.6		8.1	
		Winter, 1933/4	15.6		11.5*	
A	16	Summer, 1935	13.7	13.7	9.2	9.4
		Winter, 1935/6	16.5	15.8	11.2	13.6
B	32	Summer, 1935	8.0		4.4	
		Winter, 1935/6	11.5		6.4	

* See Fig. 6.

FIG. 5.

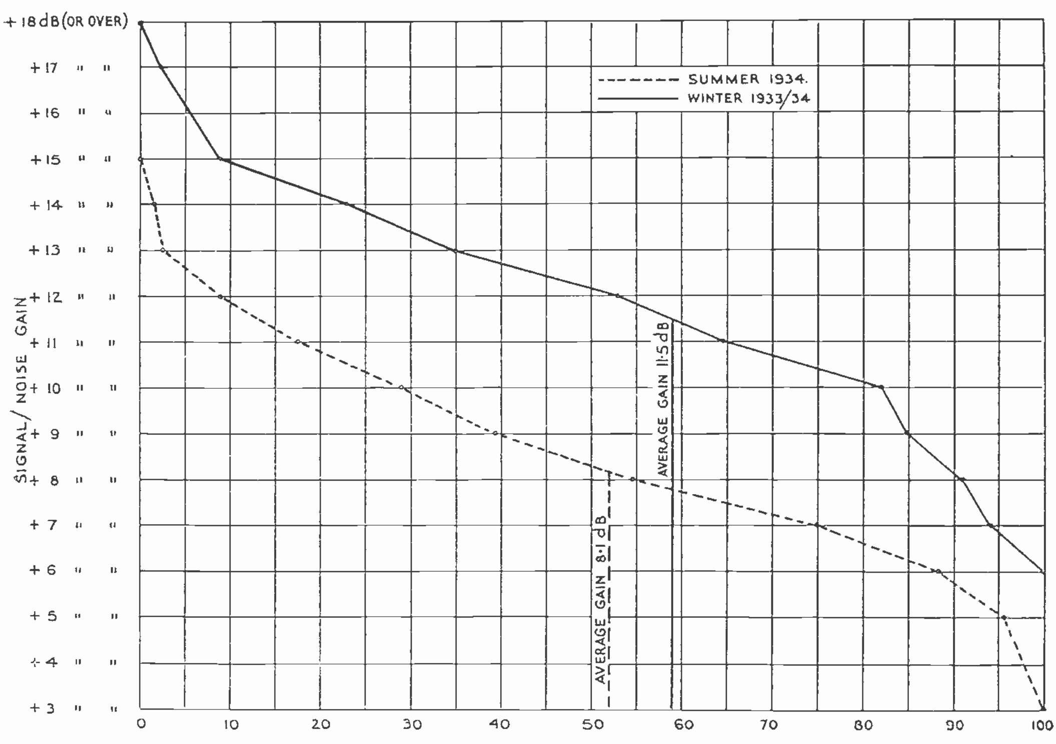


FIG. 6. *Ascension. Noise level, 16 m. Signal/noise gain of aerial A (directed on London) over λ/2 vertical aerial.*

Figs. 3 and 4 show typical values of noise-levels at Ascension, computed in the above manner. The ordinates, in fact, represent the equivalent minimum field strengths required for clean reception on a non-directive aerial.

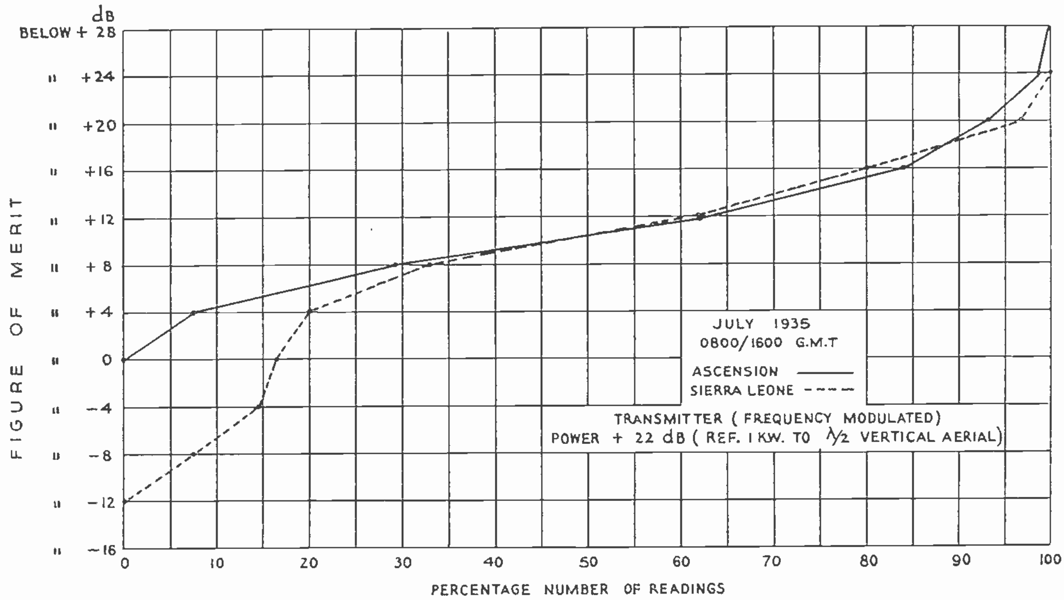


FIG. 7. 16 *m. transmission from London (directional). Comparative reception at Ascension and Sierra Leone on* λ/2 *vertical aerial.*

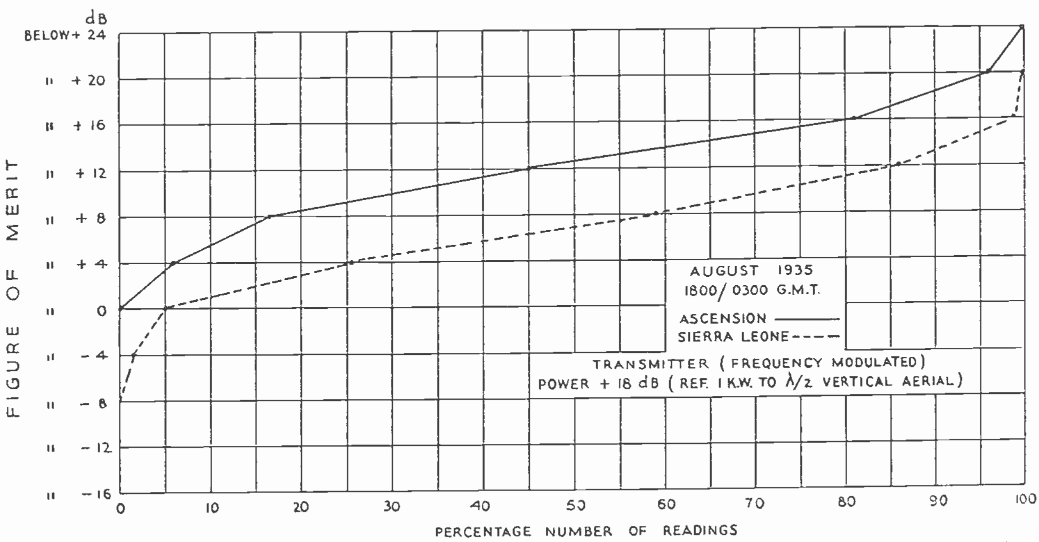


FIG. 8. 26 *m. transmission from London (non-directional). Comparative reception at Ascension and Sierra Leone on* λ/2 *vertical aerial.*

Directive Receiving Aerials for Reduction of Effective Noise-level.

If, in addition, the Figure-of-merit referred to above is compared with that obtainable on an elementary directive test aerial correctly aligned with respect to the distant transmitter, it is possible to determine the extent to which the above minimum field strength requirements can be reduced by the use of modern directional receiving aerials.

The performance of such aerials will undergo a seasonal variation due, partly to a change of geographical disposition of the source of disturbance, and partly to a variation of angle of incidence of the received signal and of interference.

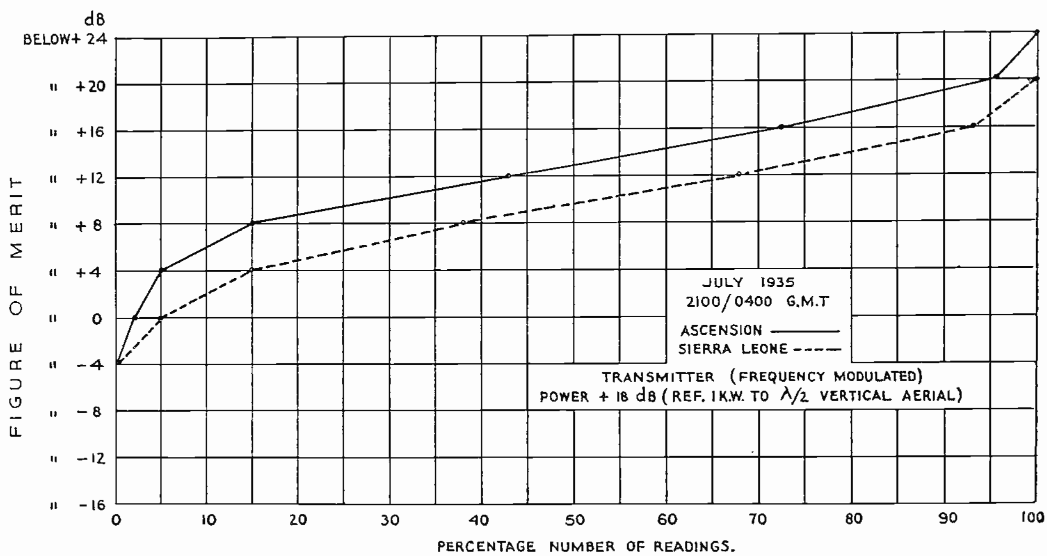


FIG. 9. *32 m. transmission from London (directional). Comparative reception at Ascension and Sierra Leone on λ/2 vertical aerial.*

Comparative results obtained at Ascension and Sierra Leone are tabulated in Fig. 5, Fig. 6 indicating the improvement in winter, in the case of Ascension, set out on a time basis.

The results obtained suggest that the probable source of atmospherics is the region of the Upper Senegal and the Niger in North Africa, during summer (N.H.), the zone of disturbance moving southwards during winter (N.H.).

Comparative Noise Measurements at Ascension and Sierra Leone.

Although no field strength measurements are available for Sierra Leone for direct correlation with Figures-of-merit obtainable on a λ/2 vertical aerial, a large number of simultaneous observations of Figures-of-merit of transmission from London have been made at that place and Ascension, using similar directive and non-directive aerials. Comparative data obtained on a λ/2 vertical aerial for 16, 26 and 32 metre transmissions are shown in Figs. 7, 8 and 9.

As far as possible, the base of the vertical aerial was arranged to be approximately six feet above ground level. The actual height, whilst of major importance

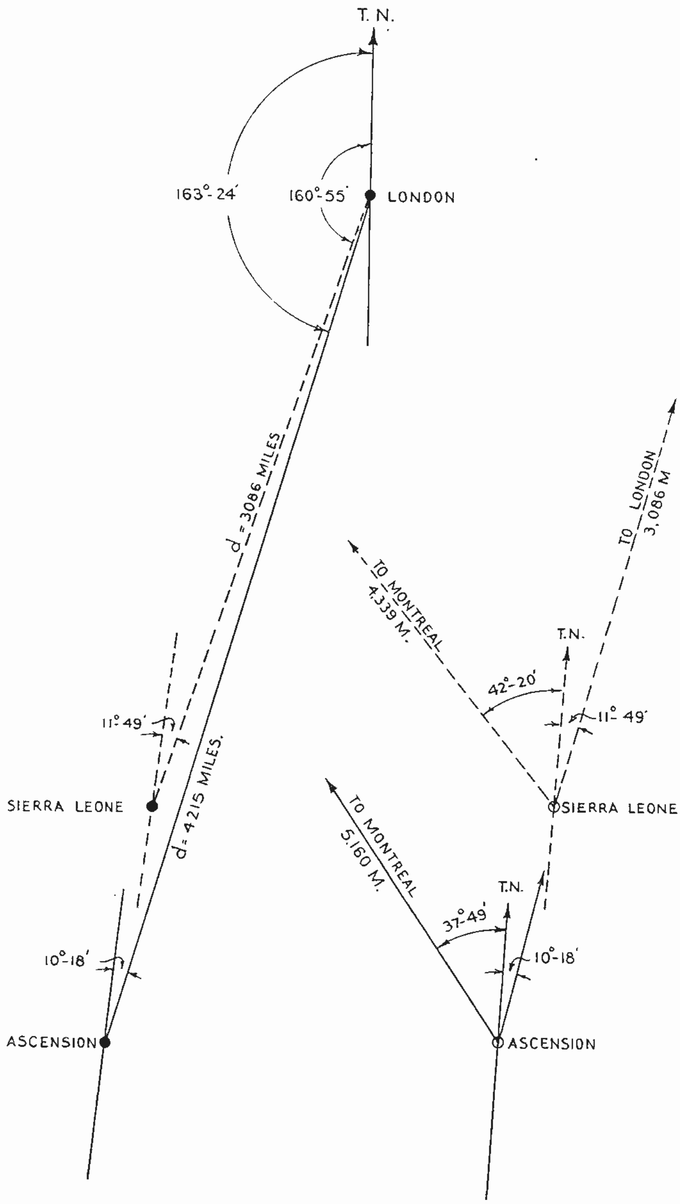


FIG. 10.

when using such an aerial as a standard of comparison for directive aerials, is considered to be of minor account when the aerial is used for the measurement of the ratio of signal and noise originating outside the skip distance for the wavelength in question. Likewise, in the case of the latter measurement, the dimension of the aerial is not critical. The relative distances and bearings from London of the two receiving points are indicated in Fig. 10; and, although the optimum wavelength

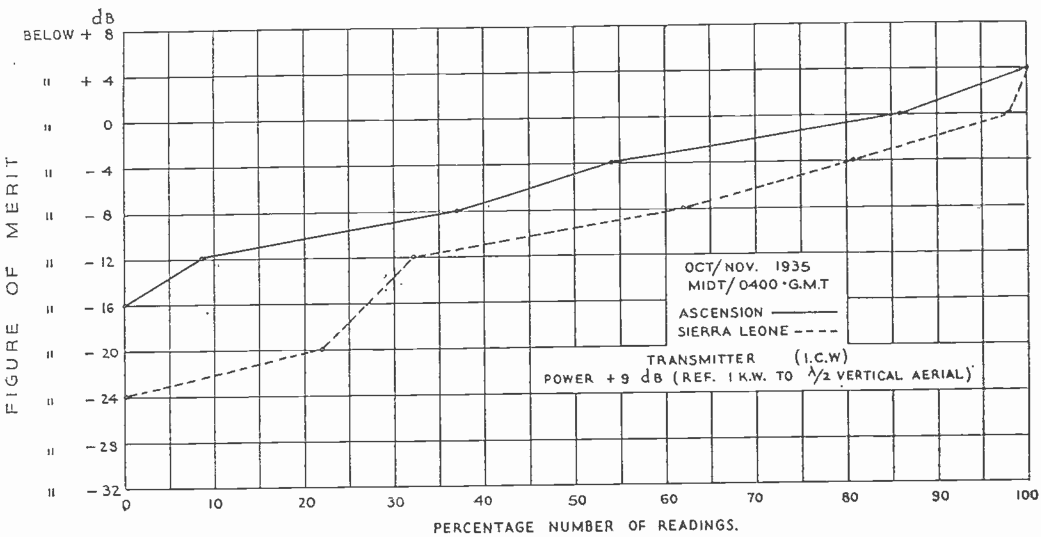


FIG. 11. *32 m. transmission from Montreal (non-directional). Comparative reception at Ascension and Sierra Leone. Receiving aerials (B) directed on Montreal.*

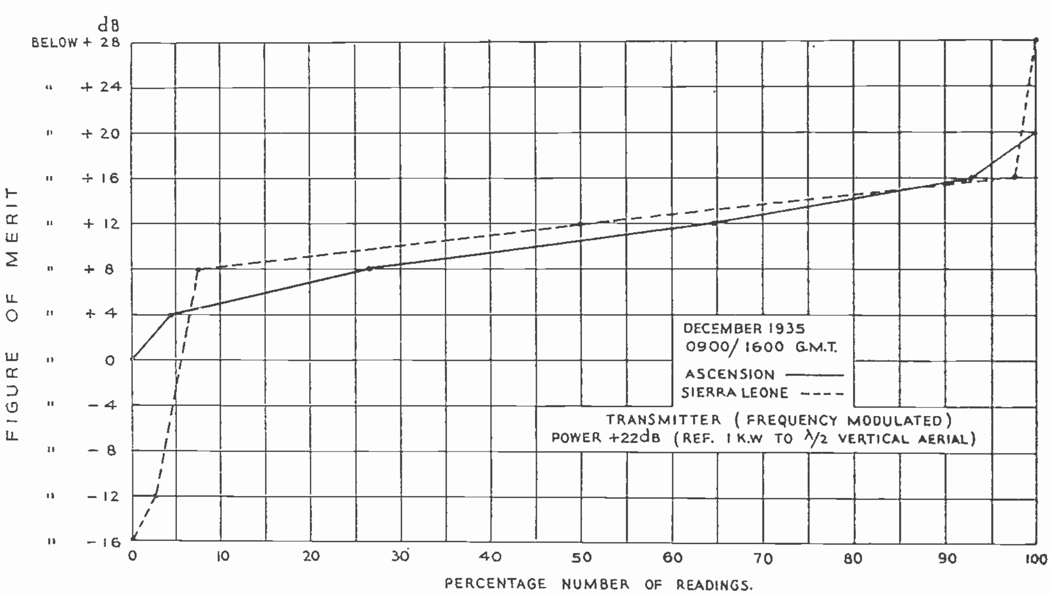


FIG. 12. *16 m. transmission from London (directional). Comparative reception at Ascension and Sierra Leone on λ/2 vertical aerial.*

at any given time will not be precisely the same for the two routes, it is evident that the noise-level at Sierra Leone is higher than that at Ascension. Analysis of the

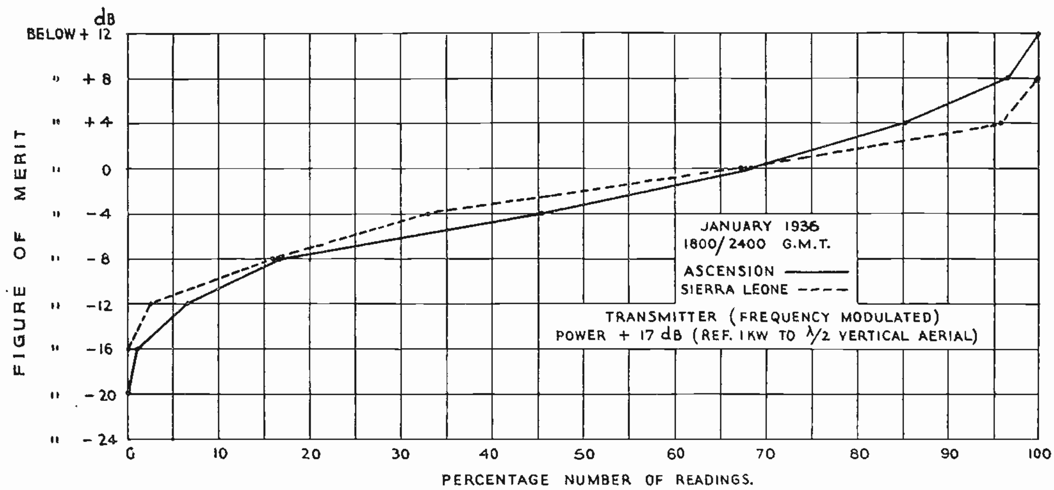


FIG. 13. 26 *m. transmission from London (non-directional). Comparative reception at Ascension and Sierra Leone on* $\lambda/2$ *vertical aerial.*

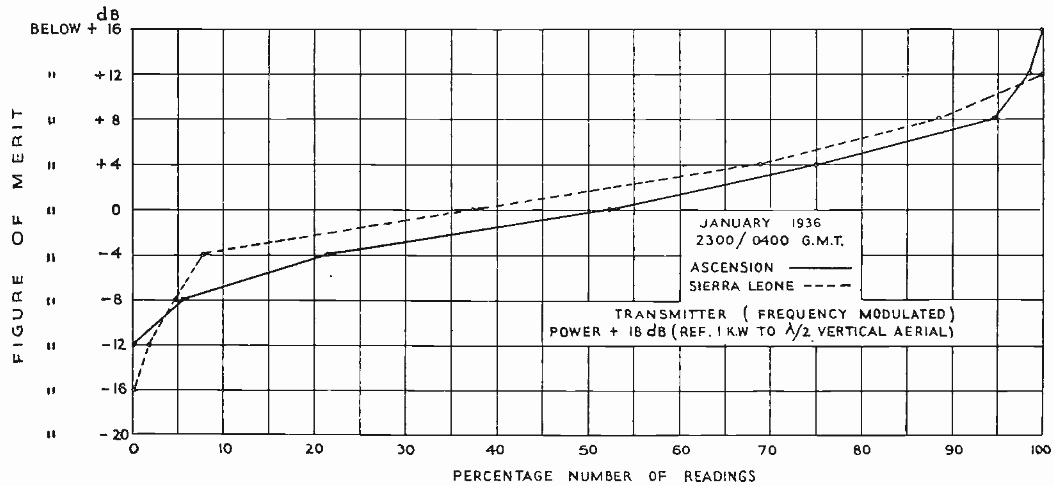


FIG. 14. 32 *m. transmission from London (non-directional). Comparative reception at Ascension and Sierra Leone on* $\lambda/2$ *vertical aerial.*

results showed that a contributory factor was the existence, intermittently, of lightning storms at Sierra Leone, notably during summer afternoons and evenings.

N.B.—In Figs. 7, 8, 9, 11, 12, 13 and 14

$$\text{Figure of Merit} = 20 \log \frac{\text{Field Minimum Signal}}{\text{Field Maximum Noise}}$$

Thus for daylight transmission on 16 metres when atmospherics are less prevalent receiving conditions are similar at the two places, except for isolated periods of local lightning at Sierra Leone (Fig. 7).

With the use of longer wavelengths for evening and night transmission, however, disturbances are much heavier and more frequent ; and it is seen from Figs. 8 and 9 that the noise-level at Sierra Leone is consistently higher.

Fig. 11 affords an additional comparison of the relative noise-levels at these two places. In this case, transmission was from a non-directional aerial at Montreal, simultaneous Figures-of-merit being obtained on similar directive aerials, aligned in accordance with the Montreal Great Circle bearings from the two places (see Fig. 10). The route distances and conditions are more similar in the case of the Montreal comparisons and, in consequence, there exists a smaller disparity in field strength.

Moreover, on the assumption of the main source of disturbance being situated in Northern Africa, the protection from atmospherics afforded by these particular directive aerials may be considered similar at the two places. (That such was, in fact, the case, was confirmed by comparison with a standard $\lambda/2$ vertical aerial.)

Under such conditions, therefore, the difference in Figure-of-merit represents, to a close approximation, the difference in noise-levels. Its value is seen to be of the same order as that obtained from the London transmissions of 25 and 32 metres.

Reduction of Effective Noise by Methods Independent of its Source.

In addition to the use of directive receiving aerials, other well-known methods of reducing the effective noise-level may be employed, e.g., the use of diversity reception at the receiver and the employment of either frequency or amplitude modulation at the emitter. Such methods considerably reduce the effective fading ratio of the received signal, and the improvement to be anticipated therefrom is independent of the position of the source of atmospherics.

Frequency modulation, as distinct from amplitude modulation, has the advantage of enabling a more useful distribution of energy in carrier and sidebands to be obtained without excessive spread.

For example, by making the frequency shift 800 c/s and the frequency of modulation 500 c/s, the main energy can be restricted to a band of $\pm$ 1,000 c/s, the component amplitudes being as under :—

Carrier	45
1st S.B.	57
2nd S.B.	26
3rd S.B.	7
4th S.B.	1.5
5th S.B. less than	1

The more even distribution of energy obtainable from frequency modulation considerably enhances the value of such a device from an anti-fading point of view.

An average reduction of 10 dB. in fading ratio has been observed when changing from C.W. to frequency modulation having the above characteristics.

A more efficient method of combating fading, however, results from the concentration of power on a single frequency, and the employment of diversity reception on suitably spaced aerials.

With such a system, a C.W. fading ratio of 20 dB. may be reduced to 13 dB. or less, equivalent to a reduction of effective noise-level of at least 7 dB.

Summary.

In order to obtain an indication of the field strength (and therefore transmitter power) required on any particular service, having regard to the time of day, season and wavelength, it is necessary to know the prevailing noise-level at the receiver and the extent to which its effect can be reduced by the use of directive receiving aerials and anti-fading devices.

Consider, for example, the case of transmission (frequency modulated) from London to Ascension at noon, winter, 1933-34, on 16 metres.

(a) **Reception on $\lambda/2$ Vertical Aerial.**

Average noise (Fig. 3) = + 7 dB. (ref. 1 μv. per metre) (and therefore minimum field strength required).

Therefore Peak Field Strength required in case of frequency modulated transmitter having fading ratio of 11 dB. = + 18 dB. (ref. 1μv. per metre).

Peak Field Strength per KW to $\lambda/2$ vertical aerial (Fig. 1) = 0 dB. (ref. 1 μv. per metre).

Therefore Power required = + 18 dB. (ref. 1 KW to $\lambda/2$ vertical aerial).

(b) **Reception on Elementary Directive Aerial.**

Assuming an average signal/noise gain of 11 dB. (Figs. 5 and 6) the above power could be reduced to + 7 dB. (ref. 1 KW to $\lambda/2$ vertical aerial). A reduction to 1 KW to a $\lambda/2$ vertical aerial could be tolerated in the case of diversity reception on suitably spaced receiving aerials, similar in type to the elementary one under consideration.

NOTE.—Figs. 12 to 14 (winter comparisons) added April 24th, 1936.

DIRECTIONAL ERRORS FROM LOCAL TRANSMITTERS

The following article discusses those types of errors occurring in direction finding systems which have been thought to owe their origin to transmitter faults and describes experiments performed in order to clear up all doubt on this matter.

It is common experience that the usual methods of radio direction finding are relatively inaccurate as compared, for instance, with visual siting. In general, even in a local calibration of a direction finder, it is unusual to find an accuracy greater than 1 degree or 2 degrees.

It has been found that a local calibration of an Adcock D.F. is more inaccurate than a distant one, especially on short waves, in spite of the fact that the distant signals are subject to distortions, lateral deviation, and polarisation shifts in the Ionosphere which lead to polarisation errors in a frame direction finder and which are not entirely eliminated in an Adcock D.F.

Some doubt usually remains in assessing the cause of the local errors observed. The D.F. receiver, the site, and the transmitter may all be under suspicion. It is usually considered, apparently without justification, that polarisation error is absent in a ground ray transmission, so that, in effect, the wave is entirely vertically polarised at a few wavelengths from the transmitter. The errors have, therefore, been attributed to either the Direction Finder or the receiving site, although some suspicion of the transmitter site remains.

Source or Diagram Errors.

Nevertheless, it is known from a theoretical point of view, that errors may be produced on account of unfavourable conditions at the transmitter. Two errors may occur which are definitely associated with the transmitter.

Firstly, if the polar diagram of the transmitter is not circular, i.e., if it does not radiate equally in all directions, there must be a radial high frequency magnetic force which, when linked with a frame aerial, will produce an error. This error, which may be called "diagram error," will decrease as the distance of receiver from transmitter is increased.

The radial magnetic field proportional to $\frac{1}{2} \cdot \frac{\delta Z}{\delta \theta}$ is accentuated near a minimum of the radiated field. Secondly, a residual polarisation error may remain. The radiation field from an asymmetrical aerial, for example an $\llcorner$ type, may not be wholly vertical. Some residual horizontal field produced by the currents in the horizontal members of the aerial may remain even at moderate distance, and produce such a distorted wave that even an ideally balanced frame in an ideal site will be subject to considerable errors. Recent experiments, made at Chelmsford, indicate that this "source error" may be very serious, and that local calibrations of a D.F. and site may be entirely useless unless due precautions are taken with respect to the transmitter.

Experiments.

Directional observations were made at Bedell's End of transmissions from the Works at Chelmsford. The distance of the receiver from transmitter was 2.96 km. The transmitter, a self oscillator of about 200 watts power input, had a wave range of some 20 to 100 m. It was the one usually used for Ionospheric work, and for convenience as well as greater accuracy, impulses at a repetition rate of 50 cycles/sec. were emitted.

The aerial was of a T type supported on two steel lattice masts 121 ft. high and 156 ft. apart, the two feeder wires of the dipole being connected together at the bottom of the aerial. See Fig. (1). The receiving site at Bedell's End was practically ideal from a direction finding point of view and was situated in the middle of an open field. The nearest trees, telegraph lines, etc., were at least 500 yards away.

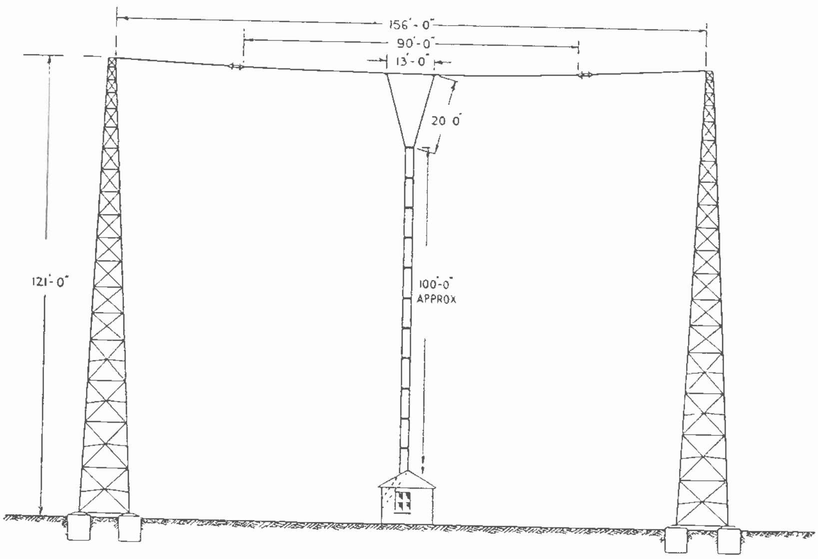


FIG. 1.

The masts of the transmitter could be seen from the receiving site, so that the true bearing could be accurately obtained by siting. Two receivers were used at Bedell's End. One was the type 205 signal measuring set. In this the frame is carefully balanced with respect to the receiver so that there should be no "vertical." Except for polarisation error or diagram error the arrangement should be a perfect direction finder for local signals. The second receiver was the newly erected spaced frame arrangement, illustrated in Figs. (2A) and (2B).

It consists essentially of a structure 20 m. across, which could be rotated about a central axis. The two frames at the ends were connected by a shielded cable to the centrally mounted hut where the receiving gear was housed. The planes of the frames were perpendicular to the line joining them and hence perpendicular to the shielded cables. At the central hut a high frequency phase balancer could be used to equalise the phase and amplitude of the signals from the two aerials and so to obtain a balance of signals on to the input of the receiver.

The output of the receiver could be connected alternatively to a pair of telephones or a cathode ray tube indicator. The arrangement measures essentially the difference in phase of the signals at the two aerials. If the two aerials are equiphased then the input signals will be balanced when the system is so oriented that the line joining

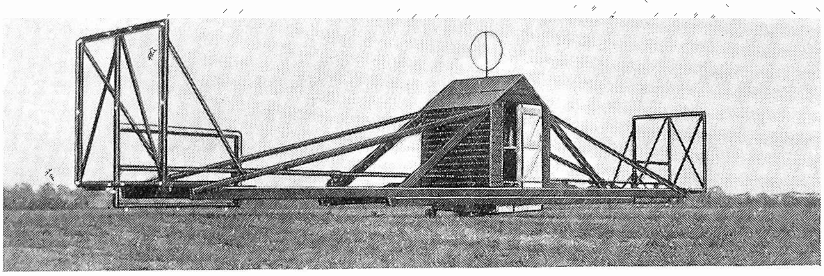


FIG. 2a.

the centres of the two aerials is perpendicular to the direction of the transmitter or parallel to the phase surface of the waves emitted. In this sense the arrangement is a direction finder which indicates the position of the constant phase surface of the waves which in normal circumstances is perpendicular to the direction of the transmitter. It will be observed that the system will indicate direction independent of the polarisation distortion to which the waves may be subject, and is also independent of the diagram error. It should, therefore, give the correct bearing and eliminate the source error, so long as the constant phase surfaces are circles centred on the transmitter.

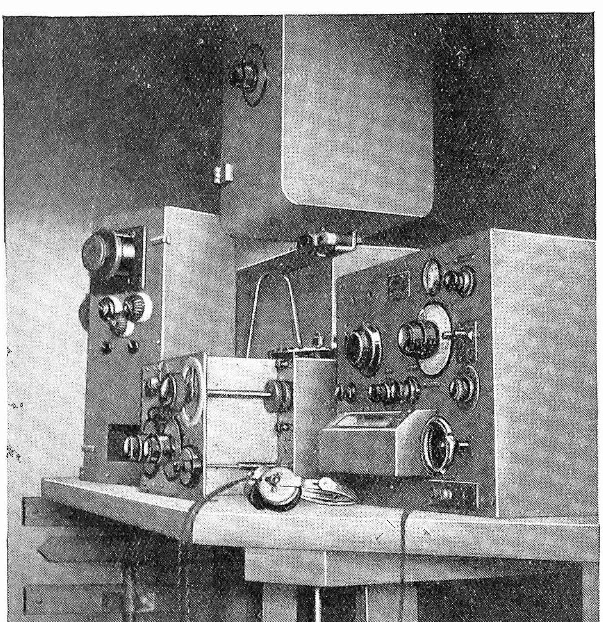


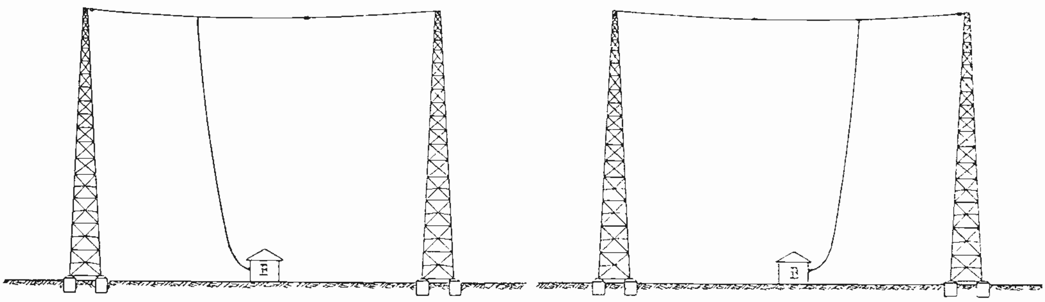
FIG. 2b.

With this arrangement each frame of the system can be used as a frame direction finder and should give zero response when the plane of the frame is perpendicular to the direction of the station. Observations were made on a 26 and 30 m. wave-length. Using it as a spaced aerial system the arrangement gave a very well defined minimum (some 40 to 50 dB) which could be set to 1/10 degrees.

On comparison with the visual direction this was found to be accurate to within 1/5 degrees (on both wavelengths). Using each single frame separately the bearings were found to be flat and indefinite on 30 m. and although fairly well defined on 26 m. were definitely in error by about +10 degrees. Each of the pair of aerials behaved practically identically in the same manner.

Every precaution was taken to avoid "vertical," the frames and leads being housed in a copper tube shield, which, as in normal practice, was split at the centre and top of the frame.

To decide whether the frames of the phase unit had some instrumental error, bearings were taken with the type 205 signal measuring set. The instrumental arrangements of the frame and coupling to the receiver differed completely from those of the phase unit, the former having an open tuned aerial and the latter an aperiodic shielded aerial. It was, therefore, extremely unlikely that the two would have the



(a) FIG. 3. (b)

same instrumental errors. Nevertheless, the signal measuring instrument behaved in a very similar manner to the frames of the phase unit. The errors, however, were exaggerated. Thus on 26 m. the bearing was sharply defined but the error was +18 degrees instead of +10 degrees. Again, on 30 m. the bearing was flat and indefinite as in the case of phase unit frames, and the error was approximately —10 degrees.

The error, therefore, was due to diagram error or polarisation distortion which was eliminated by the phase unit when used as a phase balance direction finder. That is to say, the ray and wave surface were correctly oriented but there was a radial magnetic field caused by a distortion of the polar diagram of the transmitter or by a residual horizontal field produced by some asymmetry in the transmitter. To test the matter further the semi-portable signal measurement set was moved to various places in the field and the error was found to persist up to distances of 500 m. or more, and finally a test was made at a greater distance in another open field and a similar error was found.

Suspicion naturally fell on the transmitter. It was noted that the T aerial was not symmetrical, being drawn up close to one of the masts, as illustrated in Fig. 3.

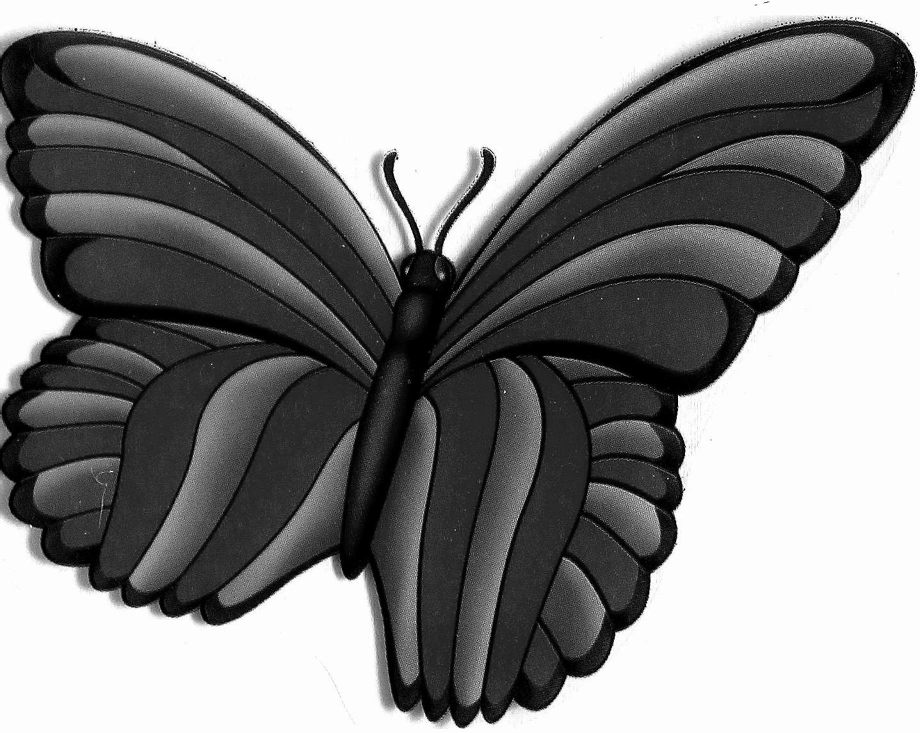
A final test was made by pulling over the aerial from the position shown in Fig. (3a) to the position shown in Fig. (3b).

On the phase unit this made a difference of only 0.2 degrees, which was practically the change in angle subtended by the midpoint C of the aerial. On the other hand, the bearing on the single screened frame of the phase unit changed 9 degrees from +12 degrees to +3 degrees. It was not accurate even in the symmetrical half way position between A and B, an effect probably due to different electrical characteristics of the two masts.

The experiments, therefore, prove that the error is definitely associated with the transmitter, a " source error " in fact which can be completely eliminated only when using the spaced frame phase unit as a direction finder.

In the case of these experiments the doubt as to the origin of the errors has been resolved. It is definitely caused by the transmitter. Thus, the use of local transmitters for calibrating a frame aerial or Adcock D.F. (where polarisation error is not wholly eliminated) is not above suspicion. Such aerials may transmit such a distorted wave that it is useless for calibration purposes. Direction finding with the spaced aerial system can, on the contrary, be made very accurate.

T. L. Eckersley.



THE MICROVOLT AND RECEIVER NOISE LEVEL

Standard signal sources at frequencies above five megacycles are liable to errors exceeding ten decibels. Noise performance data are subject to wide limits as a result of the variable precision met with when checking standard signal generators.

It may be difficult to ensure that first circuit noise having apparent characteristics of Johnson noise is not largely due to Schott effect in the grid cathode space. The effects are most noticeable at frequencies above 20 megacycles.

In the following article a case is made out for more uniform and higher precision in standard signal sources.

THE measurement of the minimum electromotive force necessary to be appreciable above first circuit noise involves a knowledge of very small but precise input signals. Such measurements are relatively simple at intermediate frequencies. At frequencies between 5 and 100 megacycles disagreement between various standard signal sources has shown that the precision of signal noise measurements can vary by at least 10 to 15 decibels. The following notes have been written with the object of pointing out where performance specifications of receivers of different manufacture may be misleading. If inaccurate standard signal generators are used in the production of such data it may happen that inferior designs allow higher margins between a stated minimum signal and receiver noise. When comparing receiver specifications the user may be inclined to accept such data in the absence of better verifying equipment, in some cases to his own disadvantage.

In high frequency communication it often happens that the limiting factor governing the minimum field intensity at which intelligence can be successfully received is receiver noise. This noise may be due to many causes, but in a well designed high frequency receiver thermal agitation noises in the first circuit should be predominant and Schott and other noises should be of negligible magnitude.

When using ultra high frequencies it is sometimes necessary to use low input impedances between the first grid and cathode circuit, in which case Schott noise will limit successful communication on very low field intensities.

Aerials having low effective heights and operating at any frequency may result in either of these noises limiting communication. It is therefore very important when comparing data applicable to various receivers that standards of equal or agreed precision be used, otherwise such comparisons are valueless.

A very practical method of indicating the noise level of a short wave telephone receiver consists in applying to the input terminals a modulated signal. The input impedance of the signal generator should be adjusted to approximate to that of some standard aerial. For example a resistive impedance of 160/200 ohms closely approximates to that measured at the centre of a half-wave vertical aerial.*

A typical noise specification calls for a total test input E.M.F. of 10 microvolts (Z=160 ohms) modulated at a depth of 40 per cent. at 400 cycles. On waves between 13 and 100 metres the signal noise ratio measured at the output of the receiver when the modulation is switched on and off should be at least 20 decibels.

---

* Measurements on half-wave aerials on waves between 300 and 15 metres has shown that the mid-impedance varies from 104 ohms to 200 ohms.

The audio frequency measuring device should be sensibly flat over a band of 50 to 10,000 cycles and be capable of measuring the R.M.S. output of the receiver. The carrier should be substantially free from scintillation during modulation.

It is important to observe that noise level should be measured at low signal inputs, and on this account the precision of the various standard signal sources should be within ± 1 decibel, otherwise performance figures relating to noise are open to abuse. Alternative methods can be devised for measuring receiver noise, but the preceding example is a typical case.

Comparisons of Accuracy of Standard Signal Generators.

On a number of occasions it has been possible to compare the accuracy of several standard sources with the standards employed by the Marconi Company. This Marconi standard is used when designing and preparing performance specifications of receiving equipment.

The results of these tests at levels below 100 microvolts and at frequencies higher than two megacycles clearly indicate discrepencies of considerable magnitude. Performance figures based upon faulty standards are misleading and do not faithfully indicate the quality of the receiver in question.

The following table summarises a few results which are quite common :—

Make.	Frequency in megacycles.	Magnitude of error decibels.	Voltage output range microvolts.
American	6	+3 decibels	1—10
,, ...	10	+5 ,,	1—30
,, ...	20	+9 ,,	1—30
British	2	+5 ,,	1—10
,, ...	6	+7 ,,	1—50
,, ...	10	+8 ,,	1—50
,, ...	20	+15 ,,	1—100
,, ...	2	+2 ,,	1—10
,, ...	6	+3 ,,	1—10
,, ...	10	+4 ,,	1—10
,, ...	20	+5 ,,	1—10

It is interesting to observe that in no case has a signal source been tested where the error has been minus at low levels. An inspection of the attenuator design will show the reasons why this result would be anticipated. The high voltage output obtained from some generators entails high impedance, and consequently on short waves the high level attenuator settings are of little value.

The above figures have been checked by using two types of standard signal sources developed in the Marconi Laboratories. These sources have been cross checked by many direct and indirect methods, and it is thought that the noise standards employed by the Marconi designers are more exacting than exist elsewhere. Practical examples have shown that on high frequencies Marconi signal-noise performance data may appear to be inferior due to better precision of measurement.

First Circuit Noise.

Although it is not the primary object of the present note to discuss thermal agitation noise in receivers, some recent noise measurements seem to suggest that in certain special cases Johnson noise can be confused with Schott effect between the grid cathode space. When carrying out such measurements on wavelengths below 20 metres the input impedance of the grid cathode circuit becomes partly resistive and this resistance may ultimately be a source of Schott noise in parallel with the first circuit.

In separating Johnson and Schott effects it has been usual to short circuit the first grid cathode path of the receiver. Under this condition the input impedance of the receiver can be made sensibly zero and Schott noise due to the space current in the anode of the valve will be measured. By removing the short circuit of the grid cathode path and tuning the first circuit to the pass band of the remainder of the receiver additional noise will be observed. In practice this noise will increase above the Schott noise by 6 to 15 decibels. The increase in first circuit noise above Schott noise will depend upon the input impedance of the first circuit, presence of Miller effect, linearity of detector and to some extent upon the input impedance of the grid cathode circuit of the first valve.

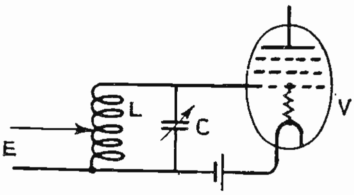


FIG. 1.

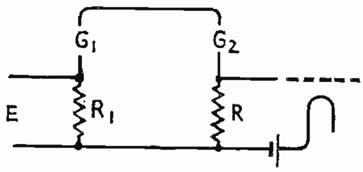


FIG. 2.

The difficulty in separating Johnson and Schott noise is apparent when it is realised that on frequencies above 20 megacycles the resistive impedance of the grid cathode path may constitute a Schott generator working in parallel with the first circuit of the receiver. Studies by W. R. Ferris in Vol. 24, p. 83, of the Proceedings of the Institute of Radio Engineers has shown that the input resistance of the grid cathode space may assume low values at high frequencies. This resistance may have the characteristics of a straightforward Schott source.

The case is shown more clearly in Figs. 1 and 2. In Fig. 1 L and C represent the first grid circuit with the applied standard signal E coupled across a portion of L. The grid cathode path of the valve V is shunted by a resistance R. The value of this resistance will be a function of the frequency and will at high frequencies depend upon the electronic condition within the valve V. The equivalent circuit is shown in Fig. 2. Here L and C are replaced by the resistance R_1 with an equivalent shunt electromotive force E. In series with resistance R_1 is shown a thermal agitation generator G_1. If the valve were perfect the grid cathode path would be non-dissipative and thermal agitation would predominate.

At high frequencies an additional generator G2 in series with a resistance R is present; the noise in this resistance R will take on the character of thermal agitation noise, whereas in fact the noise may be due to Schott and Johnson effect in the grid cathode space.

The open and short circuit test usually employed when measuring the relative magnitude of Johnson and Schott noise will not be conclusive if the diagram of Fig. 2 can be substantiated.

When using various types of valve associated with first circuit measurements improvements in first circuit noise are difficult to explain without using the assumptions described. The effects commence to be of considerable magnitude at frequencies above 20 megacycles.

S. B. SMITH.

MARCONI NEWS AND NOTES

FORTY YEARS OF WIRELESS.

ANNIVERSARY OF MARCONI'S FIRST PATENT.

FORTY years ago on Tuesday, June 2nd, Marconi filed the application for his first patent for a wireless invention. That patent—No. 12039 of 1896—was the foundation of wireless communication as we know it to-day. It described the use of Marconi's sensitive tube receiver, or coherer, connected to an earth and elevated aerial—which were the essence of Marconi's great discovery—and also described the tuning of the transmitting and receiving circuits with each other, another detail which was of fundamental importance in the development of the system.

Since that time nearly 800 patents have either been granted to Marconi and the Marconi Companies, or are pending, for the inventions and developments which, year by year, have gone to the building up of the world-wide system of wireless telegraphy and telephony, and the extensive organisation of broadcasting, which owe their existence to the genius of Marconi and which, within the span of a single lifetime, have revolutionised human standards of time and space.

Forty years ago Marconi had just introduced his first invention to Sir William Preece, Chief Engineer of the Post Office, and had demonstrated it over the modest distance of 100 yards. In succeeding months further experiments established communication over increasing distances; and by the end of that eventful year one and a half miles had been covered.

Increasing Ranges.

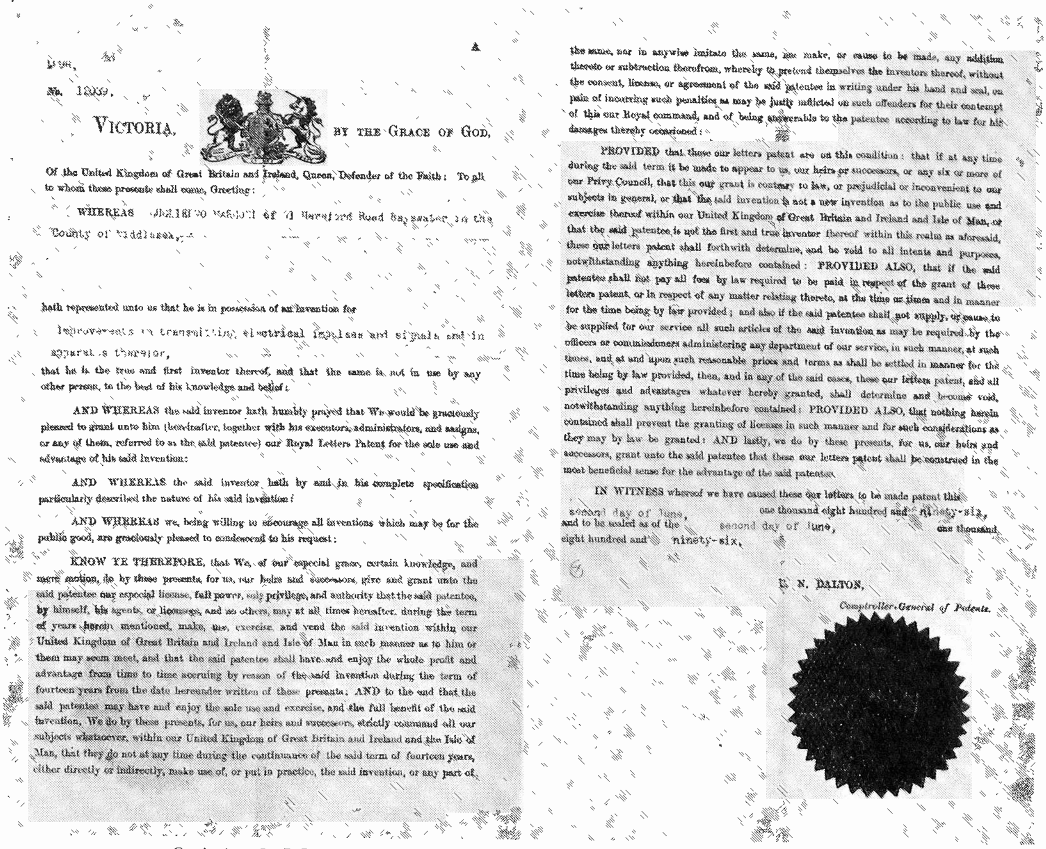
During the following twelve months greater advances were made, and the distances covered were gradually increased, first to four miles, then to eight miles, ten, and eventually to 34 miles—between Bath and Salisbury. Then came still more ambitious efforts, and in 1898 wireless installations were placed on Trinity House lightships, a demonstration was given at the House of Commons, and communication was established for Queen Victoria between her residence on the Isle of Wight and the Prince of Wales (afterwards King Edward VII) on the Royal yacht in the Solent.

The English Channel was bridged in 1899, and the Atlantic Ocean in 1901, thus finally proving to Marconi himself and to the world at large that wireless communication was possible between any two points on the earth whatever distance they might be apart.

The Marconi Company was formed in July, 1897, to develop Marconi's inventions commercially, and in spite of scientific scepticism and other obstacles steady progress was made from year to year. The first British ship was equipped with Marconi apparatus in 1901. To-day over 3,000 British ships carry Marconi wireless installations, and thousands of people owe their lives to its use.

The Empire Wireless Service.

Wireless messages were exchanged between England and Canada in 1902, and



1896,

No. 12039.

A

VICTORIA, BY THE GRACE OF GOD,

Of the United Kingdom of Great Britain and Ireland, Queen, Defender of the Faith: To all to whom these presents shall come, Greeting:

WHEREAS GUGLIELMO MARCONI of 71 Hereford Road Bayswater in the County of Middlesex,

hath represented unto us that he is in possession of an Invention for

Improvements in transmitting electrical impulses and signals and in apparatus therefor,

that he is the true and first inventor thereof, and that the same is not in use by any other person, to the best of his knowledge and belief:

AND WHEREAS the said inventor hath humbly prayed that We would be graciously pleased to grant unto him (hereinafter, together with his executors, administrators, and assigns, or any of them, referred to as the said patentee) our Royal Letters Patent for the sole use and advantage of his said Invention:

AND WHEREAS the said inventor hath by and in his complete specification particularly described the nature of his said invention:

AND WHEREAS we, being willing to encourage all inventions which may be for the public good, are graciously pleased to condescend to his request:

KNOW YE THEREFORE, that We, of our especial grace, certain knowledge, and mere motion, do by these presents, for us, our heirs and successors, give and grant unto the said patentee our especial license, full power, sole privilege, and authority that the said patentee, by himself, his agents, or licensees, and no others, may at all times hereafter, during the term of years herein mentioned, make, use, exercise, and vend the said invention within our United Kingdom of Great Britain and Ireland and Isle of Man in such manner as to him or them may seem meet, and that the said patentee shall have and enjoy the whole profit and advantage from time to time accruing by reason of the said invention during the term of fourteen years from the date hereunder written of these presents; AND to the end that the said patentee may have and enjoy the sole use and exercise, and the full benefit of the said invention, We do by these presents, for us, our heirs and successors, strictly command all our subjects whatsoever, within our United Kingdom of Great Britain and Ireland and the Isle of Man, that they do not at any time during the continuance of the said term of fourteen years, either directly or indirectly, make use of, or put in practice, the said invention, or any part of, the same, nor in anywise imitate the same, nor make, or cause to be made, any addition thereto or subtraction therefrom, whereby to pretend themselves the inventors thereof, without the consent, license, or agreement of the said patentee in writing under his hand and seal, on pain of incurring such penalties as may be justly inflicted on such offenders for their contempt of this our Royal command, and of being answerable to the patentee according to law for his damages thereby occasioned:

PROVIDED that these our letters patent are on this condition: that if at any time during the said term it be made to appear to us, our heirs or successors, or any six or more of our Privy Council, that this our grant is contrary to law, or prejudicial or inconvenient to our subjects in general, or that the said invention is not a new invention as to the public use and exercise thereof within our United Kingdom of Great Britain and Ireland and Isle of Man, or that the said patentee is not the first and true inventor thereof within this realm as aforesaid, these our letters patent shall forthwith determine, and be void to all intents and purposes, notwithstanding anything hereinbefore contained: PROVIDED ALSO, that if the said patentee shall not pay all fees by law required to be paid in respect of the grant of these letters patent, or in respect of any matter relating thereto, at the time or times and in manner for the time being by law provided; and also if the said patentee shall not supply, or cause to be supplied for our service all such articles of the said invention as may be required by the officers or commissioners administering any department of our service, in such manner, at such times, and at and upon such reasonable prices and terms as shall be settled in manner for the time being by law provided, then, and in any of the said cases, these our letters patent, and all privileges and advantages whatever hereby granted, shall determine and become void, notwithstanding anything hereinbefore contained: PROVIDED ALSO, that nothing herein contained shall prevent the granting of licenses in such manner and for such considerations as they may by law be granted: AND lastly, we do by these presents, for us, our heirs and successors, grant unto the said patentee that these our letters patent shall be construed in the most beneficial sense for the advantage of the said patentee.

IN WITNESS whereof we have caused these our letters to be made patent this second day of June, one thousand eight hundred and ninety-six, and to be sealed as of the second day of June, one thousand eight hundred and ninety-six,

H. N. DALTON,

Comptroller-General of Patents.

Original Marconi Patent No. 12039 *of 2nd June,* 1896.

a public service was opened in 1907. This linking of Canada with the Mother Country naturally led to schemes for connecting all the Dominions with England by wireless telegraphy. As, at first, it was impossible to guarantee direct transmission the schemes visualised provided for covering the distances involved first in hops of 1,000 miles, afterwards extended to 2,000 miles, then to 6,000 miles, and, finally, by direct transmission.

For direct transmission by the long-wave system the estimated power to the aerial amounted to something like 1,000 kilowatts, the stations were to cost over £1,000,000 each, the wavelengths were to be of the order of 18 miles, and the aerials were to be carried on towers about 800 feet high. These figures now seem fantastic. The number of stations that could work without interfering with one another under such conditions was limited, and it is not surprising that a leading physicist remarked that wireless had apparently reached saturation point! This was true as regards the particular long-wave method then employed; but so far as Marconi was concerned the situation simply revived his old pioneering outlook which suggested to him that a new and more efficient method must be found which would prove effective over great distances, and allow a greatly increased number of stations to be operated.

The Marconi Beam System.

This led to a wonderful series of tests between the experimental station at Poldhu and Marconi's yacht "Elettra," in 1923 and 1924, from which was evolved the Marconi short-wave beam system which enabled the Marconi Company to make an offer to the Post Office to establish communication with the Dominions using one-fiftieth of the power, involving one-twentieth of the cost, and providing a speed of working at least three times as great as that which was possible with the earlier long-wave system of communication.

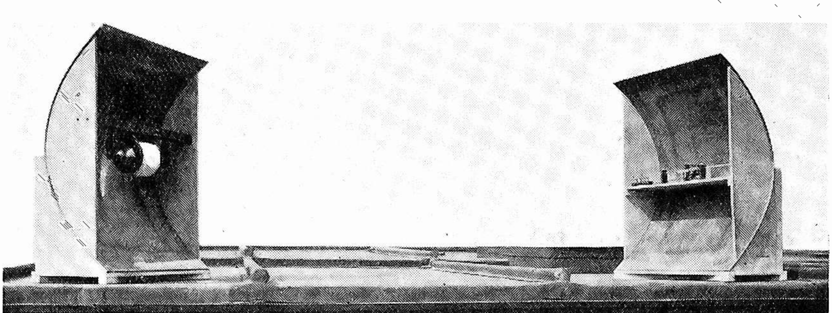
It is given to few inventors to see not only their first invention developed to a point when it is acclaimed by the whole world but also to revolutionise that invention so that an apparent limitation in its usefulness is turned into unlimited possibilities. But this is what happened to Marchese Marconi.

The Post Office accepted the Marconi Company's offer for an imperial scheme of communication, and the extraordinary success of the services provided by the short-wave imperial beam stations is a matter of history, the volume of traffic—handled at speeds up to as high as 400 words per minute—leaping to a level which had never been anticipated.

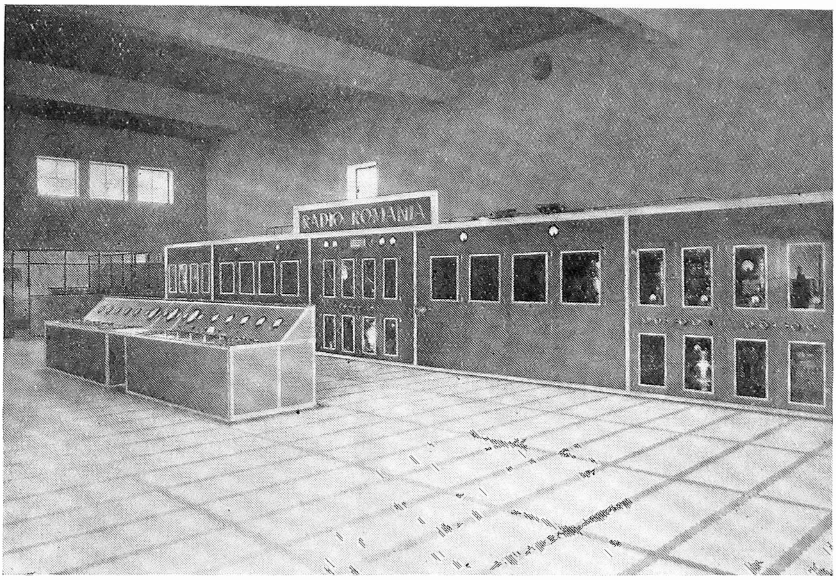
Air Services and Telephony.

Starting with communication for ships, for which wireless is pre-eminently fitted, Marchese Marconi's invention had proved equally efficient for land communications. From 1912 onwards it was introduced into the air services and is now extensively used for communication and navigation by air transport companies throughout the world, Marconi installations being used in more than 30 countries.

Experiments in telephony by wireless were first carried out by the Marconi Company in 1906, and the development of this side of wireless to world-wide telephone communication and to broadcasting is common knowledge. Regular broadcasting



Replica of Parabolic Transmitter and Receiver used in 1896.



100-*kilowatt Broadcasting Station at Bod, Roumania.*

started in England in 1922, and English broadcasting is recognised as the finest in the world. Marconi broadcasting installations have maintained England's reputation for workmanship and no fewer than 180 Marconi broadcasting stations are in use in 32 countries.

Facsimile telegraphy has been developed so that it is an everyday occurrence for photographs to be wirelessed from Europe to America and to Australia, and we are now on the verge of a further marvel in the development of television.

A New Industry.

Wireless has created a new industry and given employment to many thousands of people. The manufacture of Marconi commercial wireless telegraph stations broadcasting transmitters, aircraft and aerodrome installations, and naval, merchant marine, military and police wireless equipment provides employment for over 2,500 officials and workpeople in London and Chelmsford. Many thousands of people are also employed at the factories of companies associated with the Marconi Company in Canada, Australia, Belgium, Holland, Norway, Sweden, Poland, Checho-Slovakia, Italy, Spain, Roumania and China.

Apart from the employment provided by the Marconi Company itself, it is estimated that the wireless industry which has sprung from Marchese Marconi's inventions employs 50,000 workpeople in Great Britain, and that the British radio industry alone has a turnover of £30,000,000 per annum.

Such, in brief, is the astounding progress made during the forty years since the first wireless patent application was filed by Marconi. It indicates in some measure the debt which the world owes to Marchese Marconi and the Marconi Company for their pioneering work in the development of wireless.