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SHORT WAVE SIGNAL STRENGTH MEASURING APPARATUS

GENERAL CONSIDERATIONS

In the last number of The Marconi Review *a brief history of the design of Signal Strength Measuring apparatus was given, and a reference was made to some of the difficulties encountered in such investigations.*

In the present article the factors which contribute to the success of a Signal Strength Measuring Set are discussed, especially from the point of view of short wave working. The question of the best type of aerial system to be employed is considered, as is the effect of the instrument itself on the field to be measured. Equalisation of signals by ear is shown to be, in general, unsatisfactory, and some form of recording device should therefore be used.

The calculation of the E.M.F. induced in a frame with a given input current is described, and the calibration of the instrument is explained.

A further article of this series will be published at a later date.

WITH the ever increasing use of short wave radio communications, the need for accurate measurements of signal intensity on this wave band has become acute.

A knowledge of the power necessary for any given service depends upon such measurements, and scientific investigations of signal transmission problems can only be advanced when such measurements are made.

The application of signal measurement to the short wave band presents special problems, not the least of which is the problem of what is actually to be measured. The simple method of determining the field strength induced in a vertical aerial is hardly sufficient, in view of our knowledge of the fact that the electric field in the wave is neither vertical nor simple.

It has been suggested that this method avoids the effects of abnormal polarisation in the wave front, but our knowledge of short waves makes it appear that the so-called abnormal polarisations* are normal.

At any rate, these abnormally polarised* waves can be made use of in supplying energy to a receiver, and it seems, therefore, the wrong policy to neglect such conditions.

A frame aerial can be used to measure the components of the magnetic field both in the direction of the ray and perpendicular to the ray, and hence gives a more complete specification of the electro-magnetic field than the vertical aerial can.

It seems, therefore, preferable to use a frame aerial, by means of which both normally and abnormally polarised components can be measured, and the value of the frame is enhanced by the fact that it is much easier to calculate its effective area than it is to calculate the effective height of a vertical aerial.

It was this latter consideration which had most weight in deciding the form of aerial used.

An ideal measuring set should not modify by its presence the quantity to be measured.

Unfortunately, the presence of the shielding boxes containing the calibrating apparatus must in itself produce some modification of the field, but, if possible, this should be a minimum.

When the dimensions of the apparatus are small compared with the wave length, this acts in the first approximation as an equivalent oscillator at the centre of the box.

The secondary magnetic field from such an oscillator will consist of circular lines of force with their centres along the axis of the equivalent oscillator. If the frame is placed symmetrically on the box, there should be no coupling between this secondary field and the frame.

This can be seen more clearly from the figure (Fig. 1). With a vertical aerial it is impossible to avoid some coupling.

For such reasons a frame is used and coupled symmetrically on to a receiver as shown in Fig. 2.

In order to measure the signal E.M.F. induced in the frame aerial, the usual procedure of inducing a known E.M.F from an auxiliary source is employed.

The frame coupled to the receiver will give a response to incoming signals which can be equalised or matched by signals from the auxiliary oscillator.

* Polarised with the electric force in the horizontal plane.

This process of equalisation adds another difficulty in the short wave case which is not present in the long wave case. This difficulty is occasioned by the rapid fading of signals which may vary in amplitude over a range of 8 or 10 to 1 in the course of a few seconds.

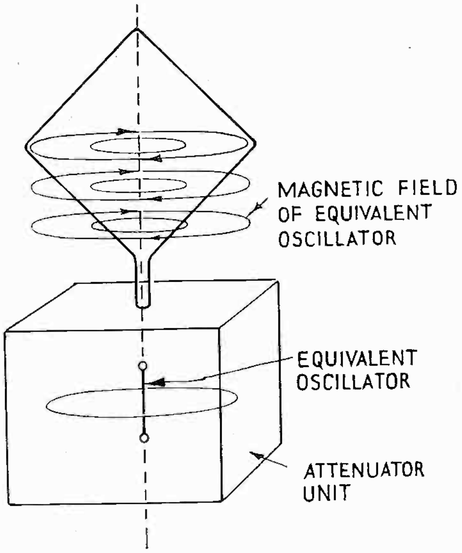


FIG. 1.

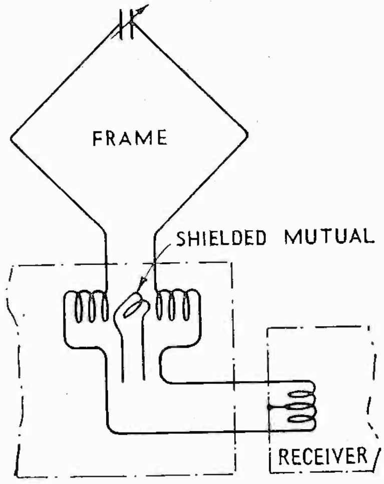


FIG. 2.

The only feasible method in such conditions is to record the signals and use the auxiliary oscillator to make calibrating marks on the record.

A receiver capable of recording the signals should therefore be used.

The attempt to match the received signals and the auxiliary signals by ear in a telephone is, in general, hopeless when the former is varying so greatly. This method can only be used on relatively local signals which do not vary. Some difficulty may be experienced in introducing the calibrating marks if the station measured is working continuously, but it seems preferable to wait for a pause in the sending rather than use a dummy frame circuit which may introduce one more degree of uncertainty.

In designing the set, an eye has been kept on continuity of design with the long wave measuring set, with the aim in view of making the same set function over the complete range of radio frequencies merely by interchanging the coils and frame belonging to it.

For this reason a certain amount of portability has been sacrificed to obtain universality and robustness in design.

In the original long wave set a mutual inductance was used to induce the auxiliary E.M.F. in the aerial, and this feature proved to be a very convenient method of continuously varying this E.M.F. A similar method was hoped to be practicable in the short wave range. This was found to be the case.

There are, however, difficulties in using a mutual alone, especially in the short wave range. The voltage induced in the frame is in many cases of long distance transmission, measured in microvolts, or even fractions of a microvolt, and it is impossible to design such a small measurable mutual inductance which will give these output voltages in the secondary with a measurable input current in the primary. Another difficulty is that the variable coupling of the mutual to the aerial reacts back on the auxiliary oscillator and changes its frequency, and absolute constancy of frequency is an essential in working, especially in the short wave band. A suitable attenuator placed between the oscillator and the frame avoids these difficulties, and the combination of the two offers very considerable advantages. The scheme therefore employed is shown in the accompanying diagram (Fig. 3).

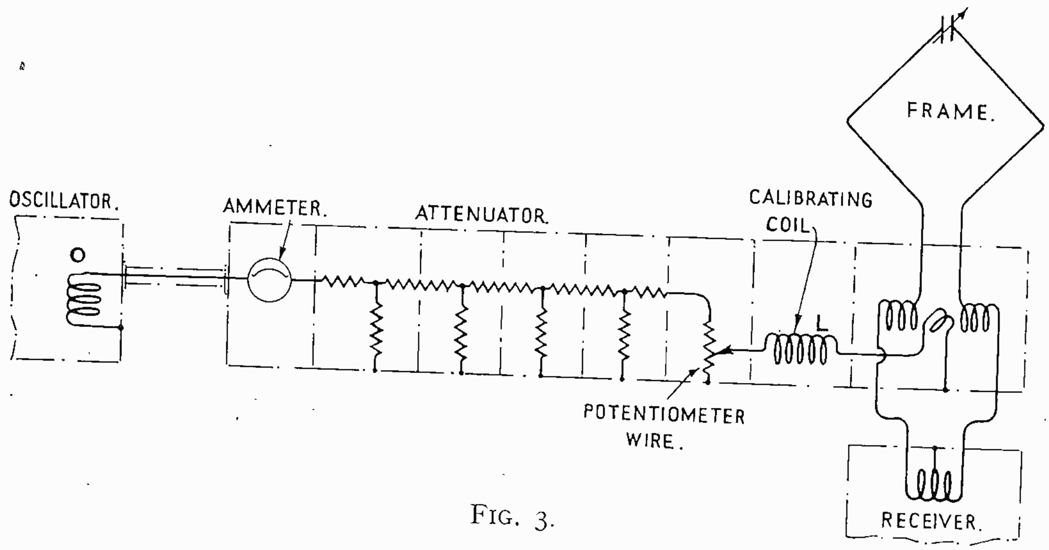


Fig. 3.

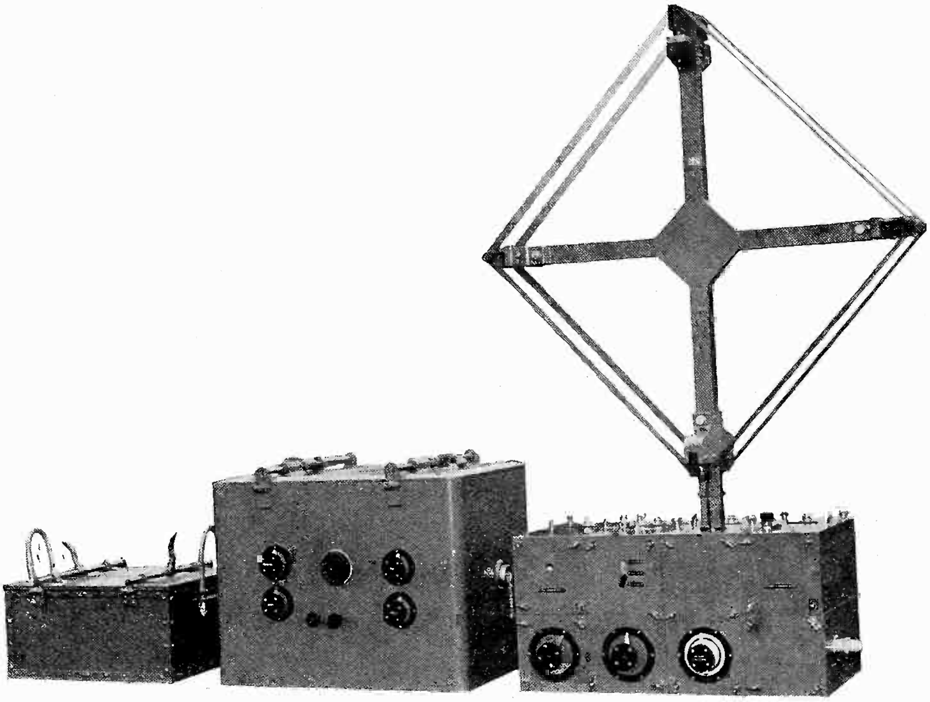
O is the auxiliary oscillator capable of supplying current at any desired frequency in the wave band (14 – 5,000).

This is coupled through an ammeter (measuring up to 125 M.A.) to a T form attenuator of about 7 ohms impedance, the output of which is passed through a potentiometer wire (7 ohms), across which is tapped the calibrating choke L and the primary of the mutual inductance, the secondary of which is part of the frame aerial, which in its turn is coupled to a suitable receiver.

The E.M.F. induced in the frame can be calculated as follows :—

Let I be the measured current in the ammeter (assumed to function correctly with sufficient accuracy up to the highest frequencies used). Then, if there are

n sections in the attenuator, each with a reduction coefficient K, the output current in the potentiometer wire is K^nI. If ρ is the resistance across which the primary of the mutual is tapped, then the E.M.F. in this circuit, including M, is ρK^nI, and the current is $i = \frac{\rho K^nI}{jLp}$ (resistance neglected), and the E.M.F. induced in the frame is $Mpi = \frac{M}{L} \rho K^nI$, and, except for slight corrections is independent of the frequency.



The performances of the attenuator and the mutual can be made to check each other, for if the auxiliary oscillator is arranged to give a definite output with a given arrangement of M and the attenuator, then the same output can be obtained by cutting out one section of the attenuator and decreasing the mutual inductance. If the latter has been calibrated, the change in its value will measure the change in attenuation of one unit in the attenuator—that is, the attenuator can be checked against the mutual, and as the former, in the ideal case, can be calculated, we can see whether the attenuator is behaving as it ideally should, and the self consistency of the calibration can be tested. This is a very important point, and there is always considerable doubt, especially on the short wave band, whether the performance is as specified, or whether small accidental capacities are producing spurious results.

Special Design Difficulties on the Short Wave Band.

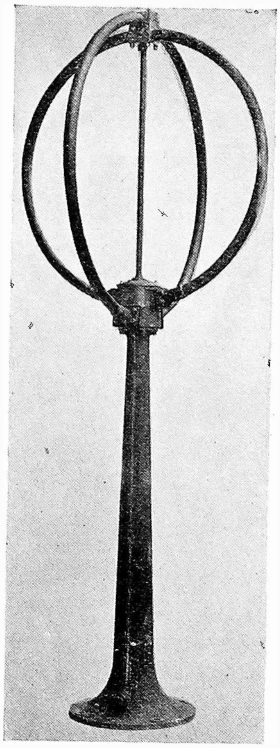
The difficulties experienced in working on very short wavelengths can be attributed almost entirely to accidental coupling capacities, and it will be realised that with frequencies as high as 2×10^7, the effect of a few centimetres coupling capacity is as great as that of a considerable condenser of 0·002 or so mfd. on the long wave band (15,000 M.). It is therefore essential to avoid such, and to obtain as nearly as possible perfect screening

(A) from the auxiliary oscillator, and

(B) between the parts of the attenuator.

To obtain perfect screening of the oscillator, this is put in a double box, and the controls are brought out through shielded holes. In the attenuator, the shielding of one unit from another requires careful design, which will be described more in detail in the next section.

T. L. ECKERSLEY.



Frame Aerial.
Type F.g.6.

SHIP TYPE FRAME AERIAL

TYPE F.g.6

The illustration shows the type of frame aerial which is used in conjunction with the type D.F.M.4 direction finder and is described in detail in the next article.

A NAVAL DIRECTION FINDER

TYPE D.F.M.4

Wireless apparatus for naval use, is in general, subjected to rougher treatment than is the case with apparatus designed for ordinary use. When such instruments are erected on board warships, where the firing of guns, etc., introduces a considerable amount of vibration, the need for substantial design and shock absorbing devices is especially important. The Type D.F.M.4 Naval direction finder was designed with the above facts in view and combines selectivity and sensitivity with great mechanical strength.

The results obtained with this instrument have fully justified the care that was taken in its design, and have proved that such an instrument is capable of giving exceptionally good results, even when used under adverse conditions.

THE Type D.F.M.4 direction finder has been designed to receive both spark and continuous wave signals of from 350–4,000 metres. This is covered in three ranges, approximately as follows :—

Range 1. 350–750 metres.
Range 2. 750–1,800 metres.
Range 3. 1,800–4,000 metres.

As in the case of the R.G.19 receiver, the D.F.M.4 direction finder has been designed for use on board warships where space is of primary importance. It will be seen from the photograph of the instrument shown below that the receiver has been made in as compact a form as possible, compatible with mechanical strength and efficiency.

The complete receiver is enclosed in two brass boxes, one containing the radiogoniometer and strength control, and the other the complete amplifier and tuner. These boxes are supported by specially designed shock absorbers.

The instrument utilises the Marconi-Bellini-Tosi system of direction finding and employs two metal shielded loop aerials mounted at right angles to each other and supported on a metal pedestal. A small unshielded vertical aerial of suitable dimensions is also used for " sense " determination.

The advantage of the Marconi-Bellini-Tosi system over any rotating frame system is that the aerials can be separated from the receiver, and can be mounted in any convenient position, both as regards pick-up and segregation from metallic masses, etc. When rotating frame aerials are used, as these act as the radiogoniometer of the direction finder, they must be mounted directly over the receiver.

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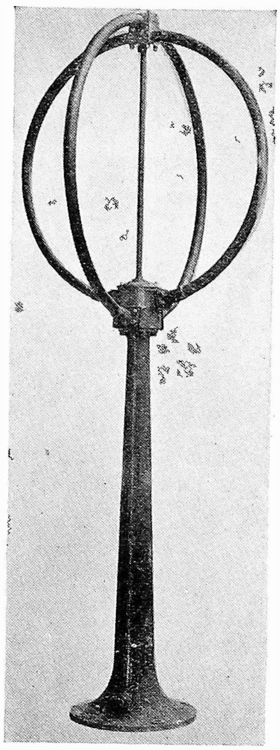

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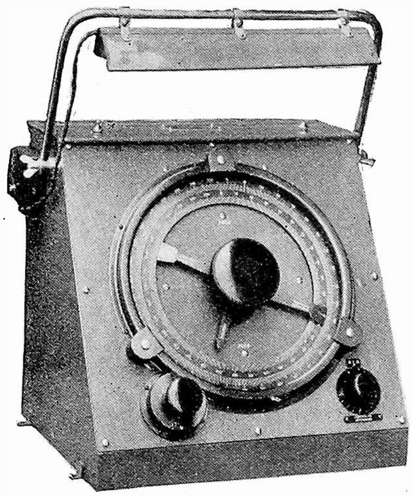
Under favourable circumstances, *i.e.*, where no masses of metal are in close proximity to the frame, no aerial correction chart is needed in conjunction with fixed aerial systems, whereas any rotating frame system necessitates the use of such a chart.



D.F.M.4 Radiogoniometer.

The Marconi-Bellini-Tosi system enables a high degree of accuracy to be obtained on all bearings taken within the extreme navigational range.

A simplified diagram of connections of the radiogoniometer and receiver is shown in Figs. 1 and 2 and a detailed description of the various components is given below.

Aerial System.

The shielded frame aerial system intended for use in conjunction with the D.F.M.4 is illustrated in the photograph on page 6. It consists, as will be evident, of two circular loops, one mounted inside the other and at right angles to it. The two are supported at a convenient height on a pedestal.

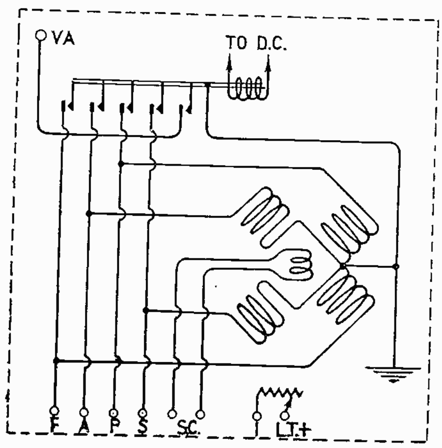
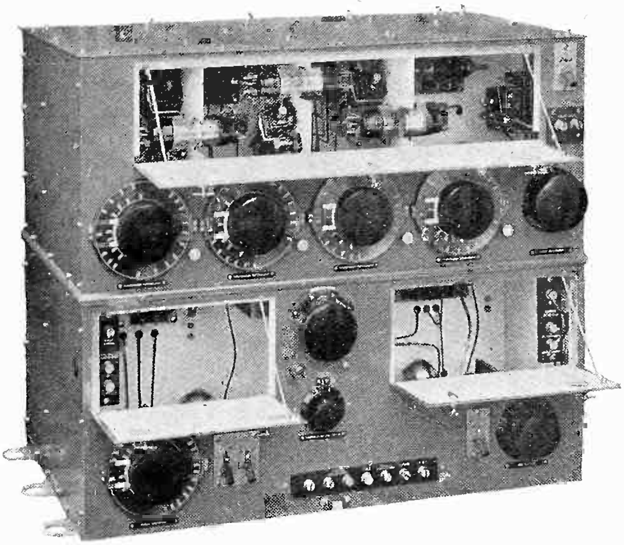


FIG. 1.

The two loops are of slightly different size, the smaller loop being placed accurately along the centre line of the vessel. The diameter of the larger loop is 4 ft. 5 in. The whole system is arranged so that it can be taken to pieces easily, the two loops being detachable from the pedestal.

Each loop is supported inside a copper tube. These tubes are bonded together at their mid-point and are connected to earth through the pedestal by means of a metal rod. Their extremities are carefully insulated from the pedestal by means of an insulated packing; this insulation being extremely important for the correct functioning of the complete system. Each loop consists of four turns of rubber-covered wire carefully insulated from the screening tubes.

The pedestal is of brass and is obtainable in various heights to suit different requirements. The leads from the two loops are connected to dry core lead-covered paper cables via suitable junction boxes and are passed through the pedestal in a convenient way and thence to a junction box located close to the radiogoniometer. Leads are taken from this junction box to the radiogoniometer terminals.



D.F.M.4 Receiver.

These frame aerials together with the vertical aerial system to be described later, enable either a figure-of-eight or cardioid polar diagram to be obtained.

Radiogoniometer.

The radiogoniometer consists of two similar field coils, fixed in position, and crossing each other at right angles. The four ends of these coils are connected to the corresponding ends of the loop aerials, as described above. The coils are mounted on a hollow cylindrical former and are well insulated from each other. A rotatable search coil is mounted symmetrically inside the former in such a manner that it can be set at any angle relative to the two field coils, and its direction read off accurately on a scale provided at the front of the receiver.

The whole radiogoniometer is mounted in a brass box with a sloping front to enable readings to be taken with greater ease and accuracy. A volume control is mounted in the radiogoniometer box, and a light is provided for illumination of the scales. These scales consist of one fixed and one rotatable 360° scale to enable either relative or true bearings to be obtained. This device has been found to be of great use in automatically eliminating a certain amount of calculation, and if operated by a gyro repeater compass greatly simplifies the operation of the direction finder.

The Receiver.

The receiver employs three stages of transformer coupled high frequency amplifiers, an anode bend detector, and a resistance capacity coupled note magnifier. A local oscillator is provided for the reception of the continuous wave signals.

It will be seen from Fig. 2 that the search coil of the radiogoniometer is connected to a closed tuned circuit provided with two coupling coils, one to the vertical aerial coupling valve, and one to the tuned grid circuit of the first high frequency valve.

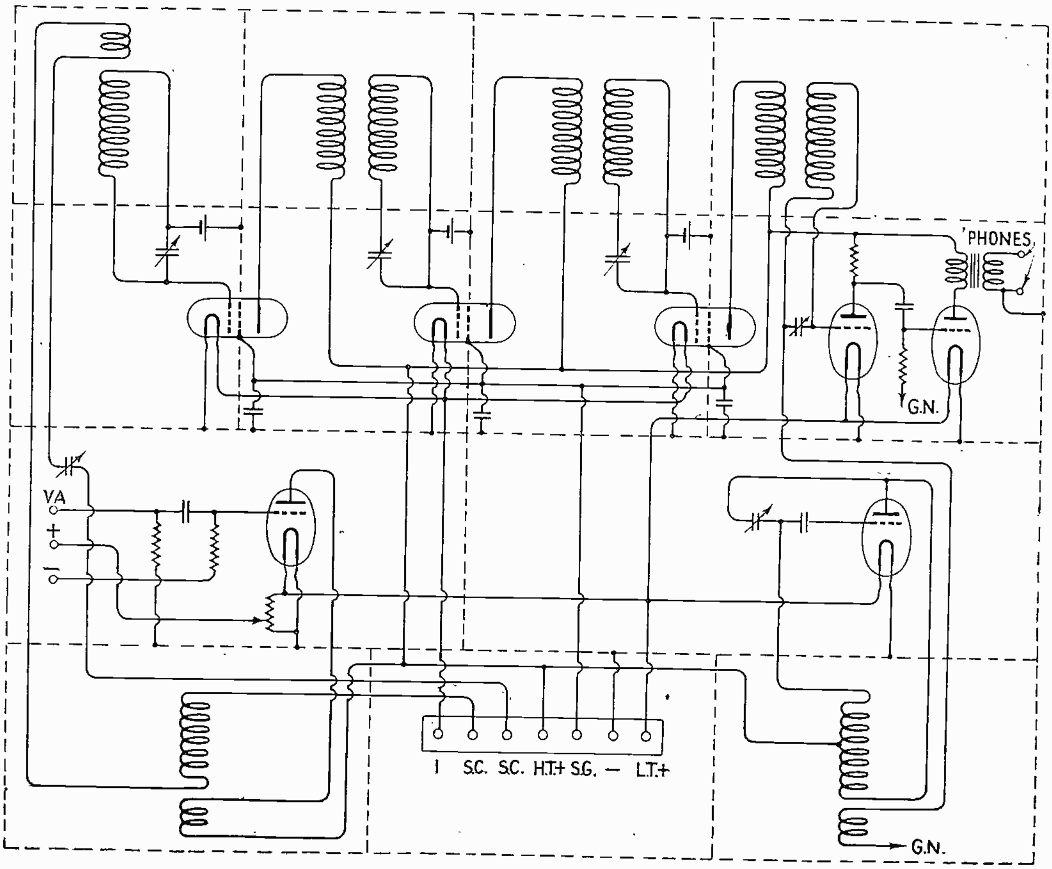


FIG. 2.

The aerial used for sense determination is coupled to the search coil circuit by means of a coupling valve. The signals are applied to the grid of this valve by means of a suitable resistance capacity arrangement. The use of such a coupling valve enables a smaller aerial to be employed, and at the same time, sufficiently good sense indications to be obtained over a large range of wavelengths without adjustment. This fact is of especial importance on warships where the use of a large aerial may be very inconvenient.

The intensity of vertical aerial signal is variable by means of adjustable grid negative on the coupling valve. This enables the correct amplitude of vertical aerial signal to be combined with the signal from the loop aerials to produce a fine cardioid diagram of reception and thus to obtain good sense indication.

The three high frequency screened grid valves are transformer coupled with tuned grid windings. The coils are astatically mounted, and the set of coils for each stage is enclosed in a separate shielded compartment of the main receiver box. The tuning condensers for the grid windings are operated individually but are provided with a gang control to enable a small band of about 10 per cent. either side of a desired wave to be searched quickly. This device facilitates tuning, as each condenser may be accurately tuned to some pre-determined wave and the final adjustment to the desired wave made by the gang control. The condensers are fitted with special scales to enable the actual wavelength in metres to be read on any of the three ranges.

The coils for the high frequency transformers are changed by means of ganged barrel switches operated from the front of the receiver by a bevel gear and shaft.

After passing through the high frequency amplifiers, the resultant signal is rectified by an anode bend detector. In the grid circuit of this valve is a coil coupling into the output of the local oscillator. The local oscillator is of the usual type and needs no special description. The connections of it can be clearly seen on reference to the diagram. Switches are provided enabling the valve normally used for this local oscillator to be employed as an extra stage of note magnification if desired.

The rectified signal is amplified still further by a resistance-capacity coupled amplifier connected in the usual way.

The receiver is designed to work with low resistance telephones, and a step-down transformer is provided with the high resistance winding in the anode circuit of the last valve.

Stability.

The question of stability has been very carefully considered in the D.F.M.4. In the case of receivers employing a large amount of high frequency magnification, it is found in general that a compromise has to be effected between high electrical efficiency of each high-frequency stage, and overall stability of the receiver.

In the case of the D.F.M.4 the combination of three stages of high-frequency magnification with small astatic coils has been found to give extreme stability and remarkably constant voltage magnification over a large range of wavelengths,

BROADCAST POWER AMPLIFIERS

The following article deals briefly with the design of the "power amplifier" type of transmitter, and with the reasons which made such design advisable as an alternative to the full power modulation method.

The question of adjustment and efficiency of a power amplifier is discussed, and a typical set of this class, the Type P.A.5 broadcast transmitter, which was described in the November number of THE MARCONI REVIEW, *is examined in detail.*

Harmonic radiation from valve transmitters is, undoubtedly, responsible for much interference at the present time, and means to avoid this are mentioned in the last part of the article.

IT will be desirable to commence by defining what we mean by a "power amplifier." Obviously, any transmitter with a driving stage includes a power amplifier, but the particular type we propose to discuss is one so adjusted as to be capable of amplifying linearly a modulated high frequency input applied to its grid. To do this the amplifier must be adjusted in a particular manner. Referring to Fig. 1, it will be seen that the left-hand diagram shows the static characteristic of a valve, and underneath a representation of an alternating voltage applied to the grid, varying above and below the point Gb., which represents the fixed negative grid bias.

The dotted curve marked "B" represents the voltage swing that would be applied to the grid if the amplifier was intended for C.W. morse transmission. It is assumed here that an increased grid swing would not increase the output, the point "B" being that at which a limit is reached either of filament emission or anode voltage. It is obvious therefore that with such a carrier setting no linear modulation is possible. Again, in the middle diagram of the same figure is shown the alternating anode volts varying about the line V_0, which is the supply voltage, the dotted curve "B" representing the conditions appertaining to a telegraph transmitter. It will be observed that the anode volts swing upwards to nearly $2V_0$, and down to nearly, but not quite, zero.

It is important that the anode voltage should not swing lower than about one thousand volts above zero, as if it does, remembering that the instant of minimum anode volts is that of maximum positive grid volts, the grid may become positive to the anode with undesirable effects due to secondary emission. It will be appreciated, therefore, that with such a plate voltage excursion as above described modulation is also impossible. To produce a condition capable of modulation, the grid input to the power amplifier must be of less amplitude than curve "B," and the anode swing likewise less than curve "B" of the middle diagram. The curves

"A" on these diagrams show an adjustment which will permit of 100 per cent. modulation without infringing the conditions laid down. This matter of the carrier adjustment of the amplifier, to make it suitable for a permissible degree of modulation, raises the question of efficiency. By the efficiency of a valve we mean the ratio of alternating power output to unidirectional power input. The efficiency of the valve is practically directly proportional to the alternating anode volts. The input power, of course, is the product of the supply voltage and the anode direct current. The output power is the product of the R.M.S. values of the alternating anode volts and the alternating anode current, and this latter is the direct anode current multiplied by a certain form factor, which depends upon the value of the grid bias.

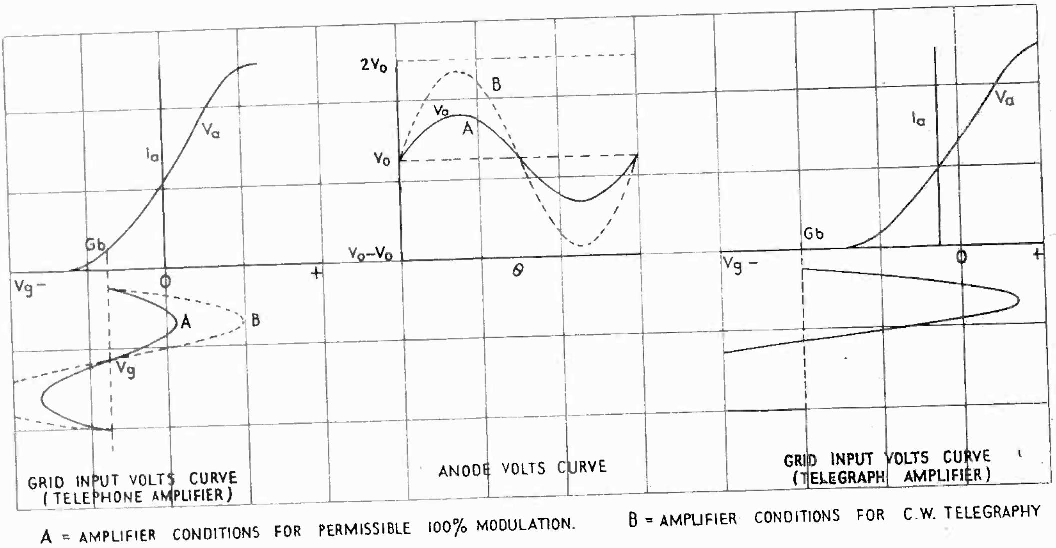


FIG. 1.

Under the working conditions of the particular type of amplifier we are considering, this form factor approximates 3·2, that is the peak value of the alternating anode current is about 3·2 times the anode current as read on a D.C. instrument. In the case of an amplifier adjusted as represented by the right-hand diagram of Fig. 1, the form factor may amount to as much as 5 or 6, and the efficiency is increased by such an adjustment of the grid bias. An amplifier of this type, however, is only suitable for C.W. transmission and anode voltage modulation, or possibly as a power amplifier for tonic train signalling, as the anode variations are no longer directly proportional to the grid input. Consideration will show that in such an amplifier the anode output may be completely modulated by a comparatively weakly modulated grid input, resulting in an amount of distortion quite undesirable in high quality telephony for broadcasting purposes.

Efficiency.

This question of the efficiency of a power amplifier adjusted for modulation is not so well understood by many as it might be. It has even been urged as an argument against the full power anode voltage system of modulation, the so-called "choke-control," that the separate modulating valves used result in a waste of power, and that the system is therefore less efficient than the low power modulation method, where no high power modulators are necessary, or than the method employing a small valve as a variable resistance in the grid of an amplifier. Actually the overall efficiency, and the total number of valves necessary for a given output, is, for all practical purposes, the same in any of the three systems.

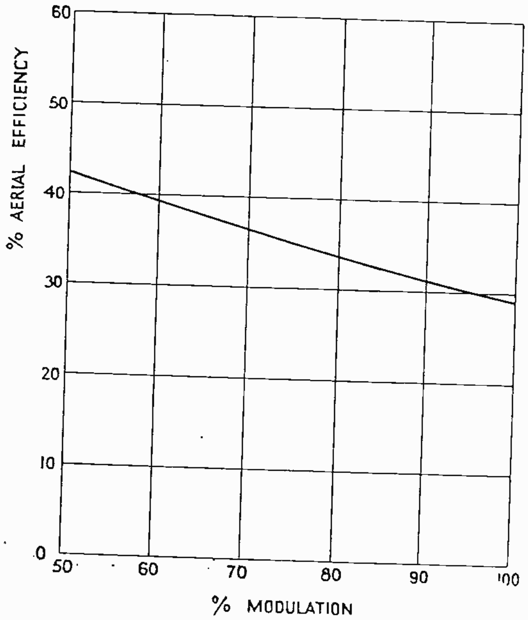


FIG. 2.

This point of efficiency being of some importance, it may be worth while to illustrate by a practical numerical example.

Let the amplifier valve be worked with a supply voltage of ten thousand and with a feed current of one ampere, that is, with an input of ten kilowatts. Assuming a required permissible carrier modulation of 100 per cent., and bearing in mind the lower limitation of anode swing to 1,000 volts above zero, it will be seen that the setting of the amplifier must be such that in the carrier condition the anode peak volts will not exceed 4,500. The peak value of anode current will be approximately 3·2 amps., and the alternating power is given by $\frac{4{,}500 \times 3{\cdot}2 \times {\cdot}7^2}{2}$ (two coming in as divisor because only half the grid swing is being utilised), or closely enough by $\frac{4{,}500 \times 3{\cdot}2}{4}$ = 3·6 kw., that is, a conversion efficiency of 36 per cent. If no modulation had to be allowed for, the anode peak volts could be adjusted to 9,000, and obviously both the output and the efficiency would be double the above values. Incidentally it follows from this that the number of valves required in a choke controlled amplifier is exactly half that necessary in a power amplifier for equal output, and assuming the valves worked to the limit of their permissible anode loss. Actually the proportion is even less, as in the former case there is no reason against using a large negative bias and operating the valves on the " flick " or shock excitation method with an efficiency greater than twice that of the power amplifier in its carrier condition.

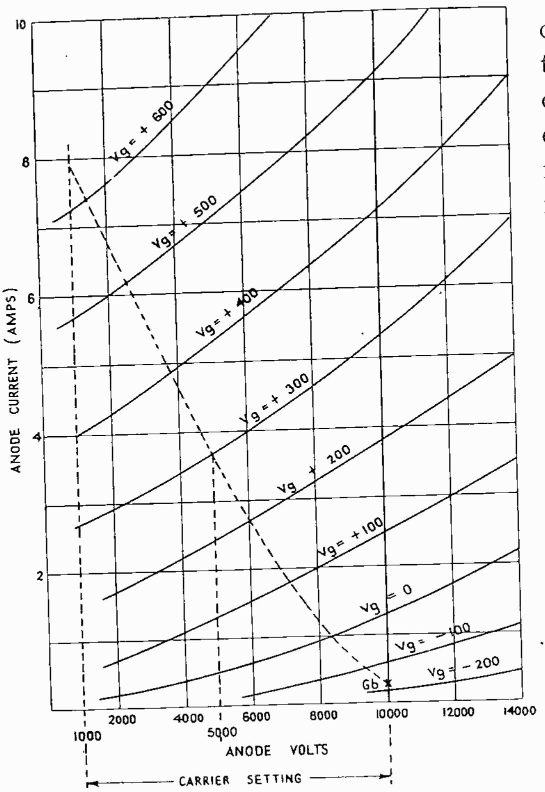


FIG. 3.

Fig. 2 is an approximate efficiency curve for a particular transmitter of the P.A. type, in which the efficiency of the amplifier, referred to aerial energy, is plotted against the adjustments for any required degree of modulation from 100 per cent. to 50 per cent. It will be seen that these values lie between about 28 per cent. and 42 per cent. respectively.

Fig. 3 shows the characteristic of a particular type of cooled anode valve manufactured by the Marconi-Osram Valve Company, and known as Type C.A.T.6, with adjustments suitable for a modulation of 80 per cent., these values, of course, referring to the positive swing of the input grid volts. It is assumed the valve is being operated at 10,000 volts with an input of 12 kw., a normal rating for such a valve. The fixed grid bias marked " Gb." is about 150 volts, giving a standing feed of approximately one quarter the anode current in the carrier condition. The driving input would be such that the anode peak volts reach 5,000 volts, a value capable of being varied 4,000 volts each way without running into bad operating conditions. Note the alternating power here is $5{,}000 \times 3{\cdot}84 \times {\cdot}25 = 4{\cdot}8$ kw., the conversion efficiency $\frac{4{\cdot}8}{12} \times 100 = 40$ per cent., and the power to be dissipated in the valve is $12 - 4{\cdot}8 = 7{\cdot}2$ kw.

Peak Voltmeter.

For studying these amplifiers and observing the working conditions, a most useful piece of apparatus is an instrument capable of indicating maximum alternating potentials between any two points in a circuit. Such a peak voltmeter is illustrated in Fig. 4. The instrument consists of a rectifier valve in series with a condenser, and shunted by a high resistance and a D.C. meter, which can be calibrated in volts. We use normally a valve of Type M.R.4 and a shunt resistance of one megohm. For anode voltage measurements, the meter is one giving full scale deflection with ten milliamperes and calibrated to read one thousand volts per milliampere. For grid voltage readings an instrument giving full scale deflection with two milliamperes and calibrated from 0 to 2,000 volts is convenient.

Reasons for adoption of Power Amplifier System.

It may be of interest to explain the reasons that influenced the Marconi Company in developing the power amplifier method for broadcasting transmitters, when for a number of years we had been using the full power modulation system with considerable success. As is well known, the modulation methods applied to broadcasting at the present time comprise three main types :—

(A) Full power modulation, generally known as the choke control system ;

(B) Low power modulation, or the power amplifier system ; and

(C) Grid resistance modulation, usually referred to as the Telefunken system.

This latter is really a power amplifier system, as the valve to which the variable grid resistance is applied has to be adjusted so as to be capable of responding to an increment in efficiency, and for a given permissible modulation the efficiency of this valve is approximately the same as a power amplifier.

Actually, in the high power German stations the modulation is carried out on an intermediate stage, and an extra power amplifier is added. We can say, therefore, there are only two distinct methods in use, viz., full power modulation and low power modulation.

The power amplifier method has been perfectly well known to us for many years. Captain H. J. Round took out a patent before the War, in which he showed an oscillating valve with modulation applied to it by driving an amplifier to increase the power to the aerial. The method is really hardly suitable for use with air-cooled valves, and in the early days of experimental broadcasting in this country, which commenced some time before water-cooled valves were available, we preferred other arrangements. At the first high power station at Chelmsford, which commenced working in 1920, and had an input of about 20 kilowatts, we used absorption control, and in smaller sets choke control, which we eventually standardised. A number of these transmitters were sold to the British Broadcasting Corporation and to broadcasting organisations in all parts of the world, and they are still providing very satisfactory service. Daventry (5XX), one of the most successful high power stations in Europe, was constructed on this system, as also was Motala, Sweden, a station with an aerial rating of 30 kilowatts. Apparently the first power amplifier transmitters to be used commercially were manufactured by the Western Electric Company of America. A number of small transmitters of this type, of about 500 watts output, were put into service in the United States, and a few were sold in Europe. These transmitters had a modulated master oscillator and one stage of power amplification, a not altogether desirable arrangement, but in later designs the modulation has been impressed on an intermediate amplifier, leaving the drive entirely independent.

A peculiar contention, which has apparently impressed many prospective customers, is the point that a power amplifier transmitter lends itself readily to any future increase of power by the addition of another amplifying stage, although why it is not appreciated that a similar addition can equally well be made to a choke controlled full power modulation transmitter is not at all clear.

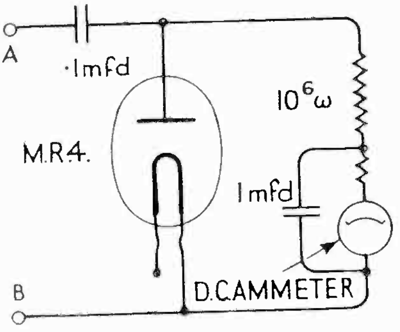


FIG. 4.

The B.B.C., however, made use of the power amplifier at their Daventry Experimental Station, 5GB, where they have obtained very successful results, and as this had considerable influence with other broadcasting organisations, and several clients requested tenders for stations of this type, with the intimation that specifications for full power modulation transmitters would not be acceptable, the Marconi Company decided to standardise a series of power amplifier sets.

Comparison of the two methods.

It has been frequently asked: "What are the comparative advantages and disadvantages of the two methods, particularly in connection with high power transmitters"? The only definite practical advantage the full power modulation method possesses is that the main valves are efficiently driven during the whole time they are in operation, and appear to be less liable to internal discharges under these conditions, while, should such occur, the short circuit current flow is limited by the high impedance of the modulation chokes. However, improvements in valve construction appear to be reducing the tendency to these discharges. A theoretical advantage to the credit of the full power system is that it is only necessary to make use of two tuned circuits carrying modulated high frequency currents, that is the main oscillatory circuit and the aerial itself, whereas in the other method several stages of amplification are usual after modulation, and consequently some care in design and adjustment is essential to avoid attenuation of the higher audio frequencies.

Some advantages of the power amplifier are that it is certainly easier to secure a level frequency characteristic when modulation is carried out on low power and with small valves and components, and the possibility of very deep modulation is more economically arranged for. In addition, no high power modulating valves are required, and the complications of maintaining these in satisfactory parallel operation consequently avoided. The overall efficiency of both methods is practically identical, any slight advantage, if existent, being in favour of the power amplifier. As to constructional costs for an equal power output, it appears this will be in excess for the full power modulated transmitter by approximately the expense of the modulation choke or transformer, which in large sets may be an appreciable item.

Type P.A.5 Power Amplifier.

The Type P.A.5 is typical of this class of transmitter, and has been described in the second number of MARCONI REVIEW. It is rated to give between 10 and 14 kilowatts to the aerial, depending on the degree of modulation required, at any wavelength between 200 and 545 metres.

In designing these sets certain features were agreed upon as essential in a transmitter at the present time. One of these desiderata was the provision of a carrier frequency unaffected by variations in the mains supply, or by modulation or other variations in subsequent stages of the set. The possibility of complete modulation was thought desirable, and, of course, as level a frequency characteristic over the useful audio range as could be obtained with a reasonable commercial efficiency. The reduction of harmonic radiation to a minimum was also considered to be of prime importance.

Commenting on the circuits stage by stage, starting with the Drive, it should be noted that the anode voltage for this stage is taken from a motor generator run off the accumulator battery which supplies the filaments. This arrangement ensures that the driving frequency is independent of fluctuations in the supply mains, and enables a very high degree of constancy to be maintained. The drive is coupled to the Isolator, which comprises a valve working without grid current in a neutralised circuit, with the result that the load on the drive remains constant, and any possible reaction back due to modulation is prevented.

Next comes the Modulated Amplifier, on which is imposed the modulation potentials through the agency of an iron cored choke coil and the modulator valve. A three thousand volt supply is used for the modulator, and the same source feeds the modulated amplifier, but is dropped to about thirteen hundred volts for this purpose by means of a series resistance. Under these conditions the modulating apparatus is capable of producing full modulation of the amplifier output.

The modulated high frequency currents are induced on to the Intermediate Amplifier, which consists of a single water-cooled valve, worked with a negative bias of twelve to thirteen hundred volts. The characteristic of this valve is such that the required output is secured without running into grid current. The load on the modulated amplifier is consequently small.

The final stage is the Power Amplifier, which in this particular set comprises three water-cooled valves working with an anode input of 36 kilowatts, and giving about 12 kilowatts carrier energy in the aerial when adjusted for 80 per cent. modulation. A slightly modified set uses four of these valves in the final stage, with an aerial rating of approximately 16 kilowatts.

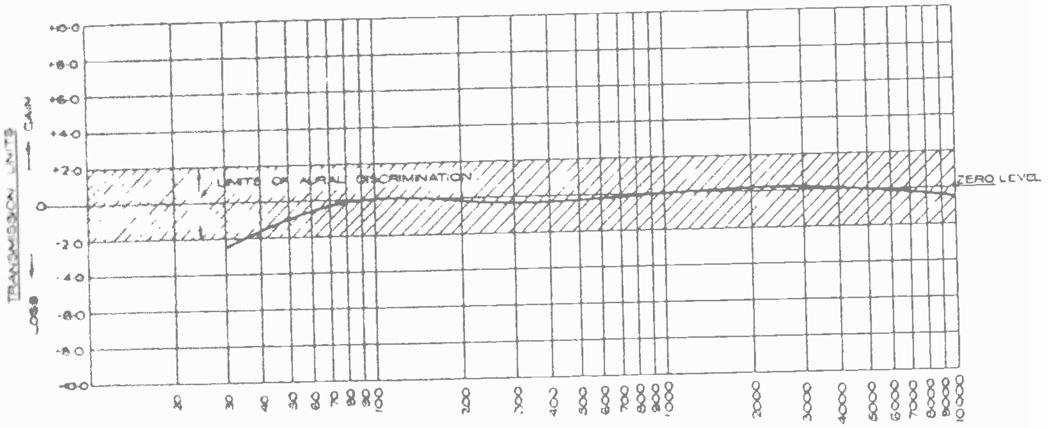


FIG. 5.

A frequency characteristic of this set is given in Fig. 5. It will be observed that this curve from 40 to 10,000 cycles is within 2 T.U. of the zero line, or alternatively, does not vary more than plus or minus 1 T.U. about a mean value. This degree of linearity means that over the frequency band mentioned the ear will be unable to detect any difference in amplitude, and consequently the curve can be considered flat over this range.

Elimination of Harmonics.

As previously mentioned, consideration has been given to the question of harmonic elimination. There is no doubt that the prevention of harmonic radiation from valve transmitters is a point of prime importance under present day conditions. Unfortunately, there appears to be no way of preventing harmonics being generated, and at the same time maintain a sufficiently high efficiency. We have, therefore, to devise means for preventing the undesired frequencies from reaching the aerial. This, again, is not a complete solution of the problem unless means are also provided for preventing radiation from the circuits and connecting leads inside the transmitter building. We have considerably reduced the trouble by placing all the tuning circuits in shielding cases, and still further improved matters by inserting a multi-

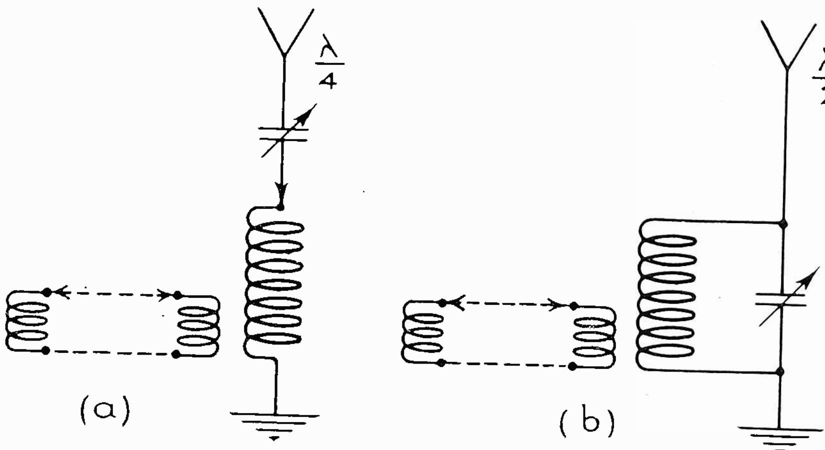


Fig. 6.

stage low pass filter between the oscillatory circuit of the power amplifier stage and the aerial. The harmonic filter is intended to work into a feeder line running to a remote building which houses the aerial tuning circuit. In Fig. 6 is a diagram of the arrangements used for the aerial coupling. It will be observed that the connections can be arranged to make the components suitable for use with either a quarter wave or a half wave aerial, or for any intermediate length.

An alternative arrangement is to connect the feeder across a coupling condenser in series with the aerial. This method tends to reduce harmonic radiation considerably, but does not completely solve the difficulty.

The harmonic filter arrangement is probably the best method at present available in combination with complete shielding of the transmitter. This, unfortunately, means increased cost, but is probably unavoidable, if the maximum freedom from undesired radiation is aimed at.

W. T. DITCHAM.

A SHORT WAVE AIRCRAFT TRANSMITTER

TYPE A.D.21

For nearly 20 years the Marconi Company has paid special attention to the question of developing wireless apparatus suitable for use on all types of aircraft. This type of communication presents certain special problems, however, and it has long been known that the use of short waves was beneficial in solving some of the difficulties which arose in this connection.

In order, therefore, to make full use of these qualities, the Marconi Company have recently designed a series of improved short wave sets, specially adapted to the above purpose.

Reference has been made, in the December number of THE MARCONI REVIEW, *to some exceptionally good results obtained with experimental short wave wireless apparatus fitted to an air-liner on the Croydon-Cairo route, and this, with other reports of a similar nature, serves to show the great use that can be made of this type of transmission and reception.*

In this article an account is given of the A.D.21 transmitter which is intended for use in conjunction with the A.D.20 receiver which will be described later.

THE Type A.D.21 transmitter is designed to work on wavelengths of from 40–60 metres and to transmit on either C.W. or I.C.W. A photograph of the transmitter is given below. It will be seen that the complete set is mounted in a wooden box with a paxolin panel. The cover is not shown. The transmitting valve—a D.E.T.1.M/8, mounted in an R.A.F. type holder—is seen in the centre. On the left are mounted the send/receive switch, the variometer, and the feed milliammeter. On the right are the tuning condenser, I.C.W./C.W. switch, and the aerial ammeter.

A 6-point plug and power lead connect the generator to the transmitter, and suitable leads connect the transmitter to the A.D.20 receiver.

The complete diagram of connections of the transmitter is shown below (Fig. 1). Fuses are provided in the positive low tension supply and in the generator field supply which is closed by the send/receive switch through a 1-ohm variable resistance. A fuse is also provided in the positive high tension supply.

The send/receive switch, in the transmit position, completes the transmitter aerial circuit, connects the filament of the valve to the low tension supply and makes the field circuit of the generator. In the receive position the receiver aerial is connected up, and the receiver valves lit. It is essential, in this connection, to note that the transmitter aerial must always be connected just before the power is put on to the transmitter to ensure that the normal load is on the valve before the latter begins to oscillate. Ordinarily, whilst transmitting, the low tension battery is floated from the low tension supply of the generator.

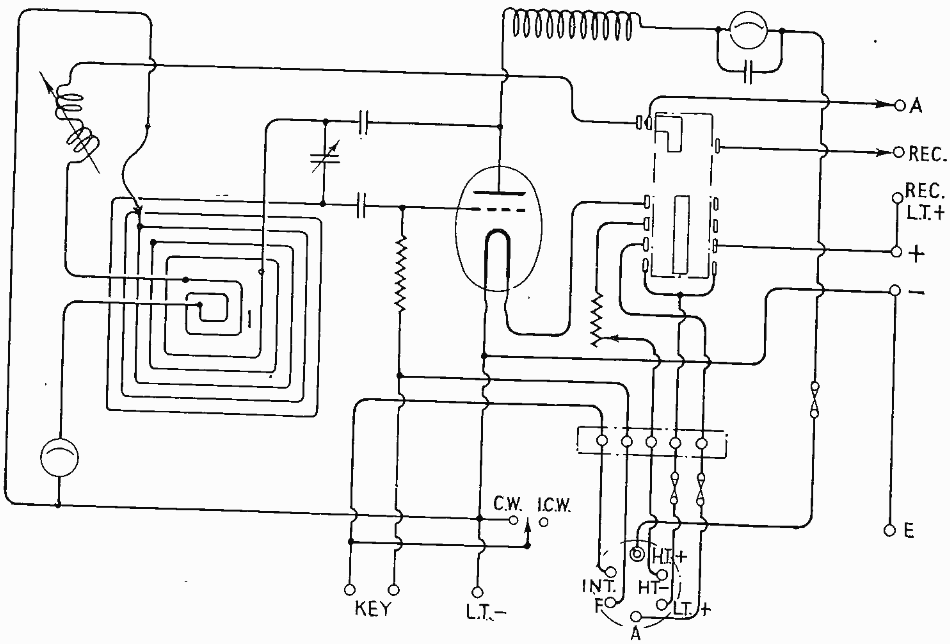
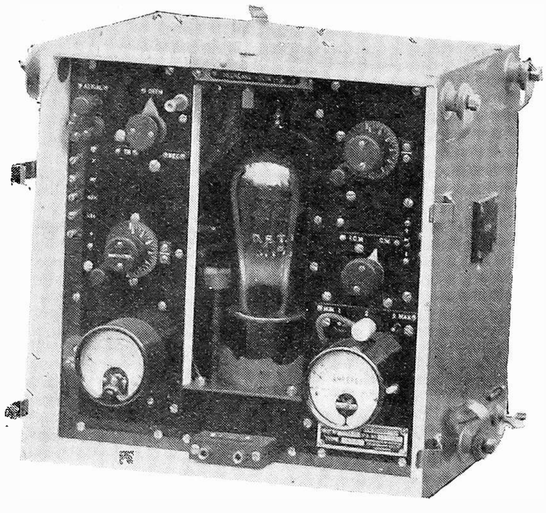


FIG. 1.

The oscillatory circuit is of a simple type and a simplified diagram of its connections is given below (Fig. 2).

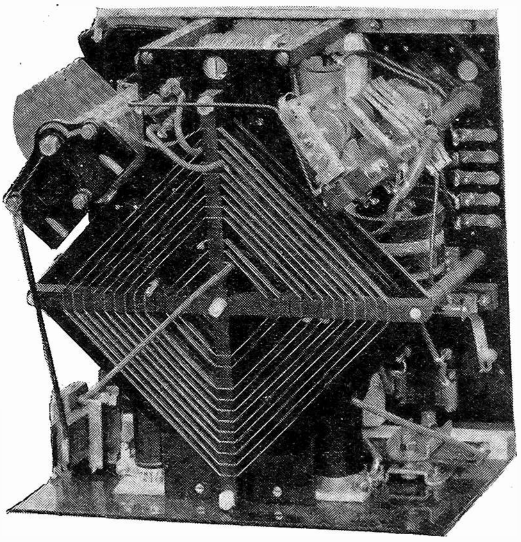


A.D.21 Transmitter. Front View.

The closed circuit inductance consists of a helical copper strip of 9 turns rigidly supported by ebonite holders on a paxolin panel and mounted at the back of the set. This is connected across the grid and anode of the valve through two condensers, one in the anode lead, and one in the grid lead. The anode condenser is of ·001 mfd. capacity, and the grid condenser of ·003 mfd. capacity. The closed circuit inductance is tuned to the required wavelength by means of a ·0007 mfd. variable air dielectric condenser operated from the front of the set. A tapping on the closed circuit inductance is connected to earth.

The aerial inductance is wound inside the closed circuit inductance, and consists of two turns of copper strip. One end of this goes through a variometer to the aerial, and one end to earth through an aerial ammeter.

The high tension supply of 1,000 volts at approximately 60 milliamperes reaches the anode of the oscillator by means of a high frequency choke wound on a glass rod and passes through a feed milliammeter which is shunted with a ·001 mfd. mica condenser to by-pass high frequency currents.



A.D.21 Transmitter. Back View.

Keying.

A 2-way switch is provided for changing over from C.W. to I.C.W. signalling. When on C.W. the rotary interrupter is shorted to earth. In this position the grid circuit of the valve is keyed through the grid leak. When the key is up, the grid, which is normally connected through the grid leak to negative low tension and negative high tension, is disconnected from negative low tension. In this way the positive potential of the anode with respect to the filament is removed with the result that no anode feed current passes. In other short wave transmitting sets it has been found that the normal arrangement whereby the grid circuit is broken, while the anode is still kept at its high potential with respect to the filament, permits a feed current to pass through the valve even although the key is up.

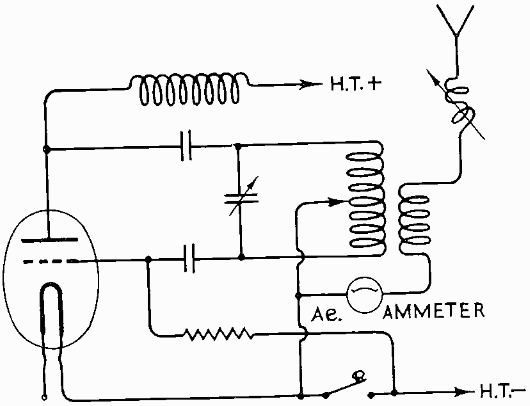


FIG. 2.

In the I.C.W. position of the switch, the grid is keyed in the same way, but a suitable interrupter mounted on the H.T. generator serves to break the H.T. supply at a frequency of approximately 750∿.

The generator used in conjunction with the set is of the A.D./B.4 type and delivers a H.T. supply of 1,000 volts at 75 milliamperes, and an L.T. supply of 7·5 volts at 4 amperes, at a speed of 3,500 r.p.m.

THE TRANSMISSION UNIT

The use of the "Transmission Unit" as a measurement of the power loss along a line is becoming almost universal. It is found, however, that some misunderstanding has arisen as to the reason for the adoption of the unit, and also as to its use.

The following article, therefore, attempts to explain briefly :—

1. *The reason for the use of the T.U.*
2. *The relation between the T.U. and the other units that have been used.*

THE transmission unit (T.U.) was introduced by the Bell Telephone Co. and was given International recognition at the September, 1927, meeting of the International Consultative Committee on Long Distance Telephony at Como.

The International unit was given the name of Bel, which is equal to 10 Decibels, or in other words 10 T.U.'s.

The new transmission unit was adopted to replace the use of the mile of standard cable which was liable to introduce errors into calculations, primarily due to the fact that whenever the transmission equivalent of a line was obtained by actual test or calculation, the terminations of the standard cable must also be stated, as it is important to know whether the standard cable is free from terminal reflections or has receiving terminations similar to those of the line under consideration.

Also in addition to the volume reduction, there is also a distortion effect introduced by the standard cable. In all carrier and radio work also the mile of standard cable has no significance.

The definition of the T.U. is as follows : "If the power ratio of the input and output power along a line is $10^{0.1}$, *i.e.*, if there is a loss of power in this ratio, then there is said to be loss of 1 T.U. in the line. Similarly, if there is a loss of power in the ratio of $10^{N \times 0.1}$ then we may say that there is a loss of N T.U.'s in the line."

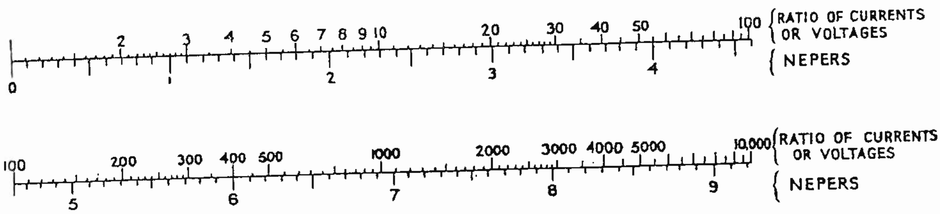
It should be noticed that the value of $10^{0.1}$ power ratio is midway between the two values which were originally used, namely, $e^{0.100}$ which was used for transmission testing work, and $e^{0.122}$ which is the average equivalent attenuation of voice currents in standard cable.

It should also be noted that the T.U. is essentially a measure of ratio of power and not of voltage or current.

It will therefore be seen that the number of T.U.'s or decibels loss or gain is calculated by multiplying the common logarithm of the ratio of the input and output powers by 10, or the input and output currents or voltages by 20. Thus :—

$$\begin{pmatrix}\text{No. of T.U's} \\ \text{or decibels}\end{pmatrix} = 10 \log \frac{Pi}{Po} = 20 \log \frac{Ii}{Io} = 20 \log \frac{Vi}{Vo}$$

NOTE I. In the case of several lines of different characteristics in series with each other, and in other cases where power ratios would, in the ordinary way, have to be multiplied in order to arrive at a final result, it is useful to note that the corresponding T.U's have to be added. This results in a great simplification of calculation in many cases.



NOTE II. There is also a voltage or current ratio unit based on the Napierian or Hyperbolic system of logarithms which differs in value from the Bel and Decibel. The number of "nepers" is obtained as follows, using hyperbolic logs :—

$$\text{No. of nepers} = \tfrac{1}{2} \log e \frac{Pi}{Po} = \log e \frac{Vi}{Vo} = \log e \frac{Ii}{Io}$$

It will be found by a simple calculation that

$$1 \text{ neper} = 8{\cdot}67 \text{ T.U's or decibels.}$$

NOTE III. It is also of interest to note the attenuation of a *mile of standard cable* = $e^{\cdot 109}$ at 796 cycles per second, whereas the T.U. corresponds to an attenuation of $e^{\cdot 115}$, which is in fact the attenuation of a *mile of standard cable* at 890 cycles. For all ordinary telephonic purposes it is convenient to consider that a loss of one T.U. corresponds to the loss on one mile of standard cable, 20 T.U's on 20 M.S.C's and so on.

As this article does not attempt to deal at all fully with the subject of the Transmission Unit, the following references are given for those who are interested and who wish to examine the subject in greater detail :—

M. P. Weinbach. "Principles of Transmission in Telephony." Macmillan, 1924.

H. Martin. "The Transmission Unit," *Jour. A.I.E.E.*, June, 1924.

R. V. L. Hartley. "The Transmission Unit." "Electrical Communication." July, 1924.

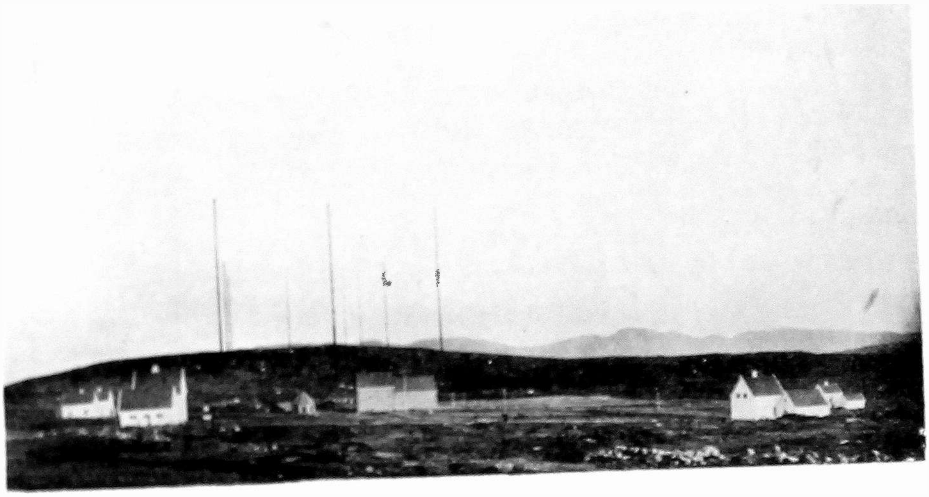
T.U. Conversion Table.

No. of T.U's	Power ratio	Voltage or current ratio	No. of T.U's	Power ratio	Voltage or current ratio	No. of T.U's	Power ratio	Voltage or current ratio	No. of T.U's	Power ratio	Voltage or current ratio
1	1·26	1·122	11	12·6	3·55	21	126	11·22	10	10	3·16
2	1·58	1·26	12	15·8	3·98	22	158	12·6	20	10^2	10
3	2	1·41	13	20	4·46	23	200	14·1	30	10^3	31·6
4	2·5	1·58	14	25	5	24	250	15·8	40	10^4	100
5	3·16	1·78	15	31·6	5·62	25	316	17·8	50	10^5	316
6	3·98	2	16	39·8	6·3	26	398	20	60	10^6	1000
7	5	2·24	17	50	7·1	27	500	22·4	70	10^7	3160
8	6·3	2·51	18	63	8	28	630	25·1	80	10^8	10000
9	7·95	2·82	19	79·5	8·95	29	795	28·2	90	10^9	31600
10	10	3·16	20	100	10	30	1000	31·6	10	10^{10}	100000

The scale connecting Current and voltage ratios with nepers is taken from "Les Filtres Electriques," by Pierre David. Publishers: Gauthier-Villars et Cie, Paris.

MARCONI NOTES AND NEWS

NORSK MARCONIKOMPANI'S TENTH ANNIVERSARY



STAVANGER WIRELESS STATION, *the Norwegian wireless station which carries on long-distance wireless communication*

The Norsk Marconikompani has celebrated the 10th anniversary of its establishment by the publication of an attractive brochure sketching the history of the company and the part it has played in the advance of the art of wireless.

This brochure is attractively produced and is illustrated with photographs of Senatore Marconi and Directors of the Norsk Markonikompani, together with photographs of the Company's offices and works, of the airship "Norge" and Norwegian ships fitted with Marconi apparatus.

The first ships in the Norwegian mercantile marine to introduce the Marconi system were Fred Olsen's boats on the Oslo-Newcastle route in 1900. In the same year Messrs. Storm, Bull & Co., of Oslo, became the Marconi Company's general agents for Norway, and as a result of this step great progress was made, Marconi wireless stations being installed on a number of mercantile vessels and warships. Courses of training for radio telegraphists were arranged to meet the needs created by these developments, and even during the War the Marconi Agents were able to meet the requirements of radio material for the Army, Navy and the Mercantile Marine.

Senatore Marconi's sensational triumph in bridging the Atlantic in 1901 gave the late Director of Telegraphs Heftye the idea of establishing wireless communication between Norway and America. At that time Norway had not even a direct cable over the Atlantic and was dependent on other countries for this communication. The establishment of a cable was out of the question owing to its cost, but the building of a wireless station held out the possibility of direct telegraph communication between Norway and the United States and other countries at a cost which was within a figure that could be contemplated. As a result of the State's negotiations with the Marconi Company Stavanger Radio was established, though its operation for commercial services was postponed, owing to the war, until 1919. This wireless station has been of the greatest value to Norway and has been instrumental in strengthening to a high degree the bond between the home-land and Norwegians who have emigrated to other parts of the world.

Since the opening of this station practically all Norwegian telegraph traffic with America has passed through Stavanger Radio.

The Formation of the Company.

Technical development went forward with such great strides during the years of the war that it was natural for Norway in common with other countries to contemplate the utilisation of the Marconi Company's patents on a national basis; and in September, 1928, the Norsk Marconikompani was formed. The requisite share capital was subscribed immediately, to a considerable extent by Norwegian shipowners, and the Norsk Marconikompani began its activities on January 1st, 1919.

Norway was thus the first Scandinavian country to establish a Marconi Company, a matter of great importance having regard to its leading position in the domain of shipping in Northern Europe.

The Company's Managers for the first year were Messrs. Storm and Bull, who had performed meritorious work in the development of the Marconi system in Norway prior to the establishment of the Company. That firm gave up the Management in 1922, and since that date the Chairman of the Board has been Norway's senior shipowner, Mr. Otto Thoresen, whose rich experience in the world of shipping has been a valuable support to the Company. Engineer E. Skottun, who had been connected with Storm, Bull & Co., since 1910, as chief of the firm's technical department, was appointed Managing Director of the Company. He has thus participated in the building up of the Marconi system in Norway for 18 years, during which period about 400 Norwegian ships have been fitted with Marconi apparatus. In recent years the Company has manufactured wireless apparatus for the Norwegian Mercantile Marine in collaboration with the parent company in London, association

The Airship "Norge" which was fitted with Marconi wireless transmitter, receiver and direction finder for its Arctic expedition

with which has been of the greatest benefit to the Norwegian Company, who have thus been able to avoid costly experiments and to benefit by the parent Marconi Company's greater experience. Another advantage of this has been that it has been possible to adjust the Norwegian installations to Norwegian conditions.

Wireless on The Norwegian Whaling Fleet.

One of the most important activities of the Norwegian Company has been the fitting of ships of the Norwegian whaling fleet which carries on an important Norwegian industry in the Antarctic.

The Norsk Marconikompani also operates a great number of wireless stations on working contracts with shipowners, these vessels including all passenger ships to America and the regular cargo vessels, together with most of the floating whale factories and whale catchers where effective radio communication is demanded. These ships further enjoy the advantages of the Associated Marconi Companies' organisations, such as the repair of wireless equipment in foreign ports and special traffic facilities.

An important development in 1923 was the installation of a powerful radio station on the whaling factory ship "Sir James Clark Ross." The demands on this installation were very great, as the ship was operating in waters thousands of miles from any radio station. Its operation, however, was extremely satisfactory, and the communications of the expedition with the outer world were never interrupted. Marconi telegraphists who accompanied whaling expeditions the following year began testing with short waves which then seemed to offer great possibilities, and in 1925 the "Sir James Clark Ross" succeeded in bringing about the first short wave communication over the Pacific Ocean to San Francisco, 8,000 nautical miles away, an achievement which created world-wide interest.

While none of the Norwegian coast stations possessed short wave equipment, Bergen Radio was fortunate in having a chief who was greatly interested in short wave communication, and on February 11th, 1927, a series of communications was initiated between the Marconi station on the "Sir James Clark Ross" and Bergen Radio. Subsequently, the Norsk Marconikompani installed a number of short wave stations on some of the larger passenger ships and on a number of whale factory ships so that these might at any time be in direct communication with Bergen Radio a matter of great importance from a social and economic point of view for a country like Norway with great marine and whaling interests, but without telegraph, cable and coast stations of its own abroad.

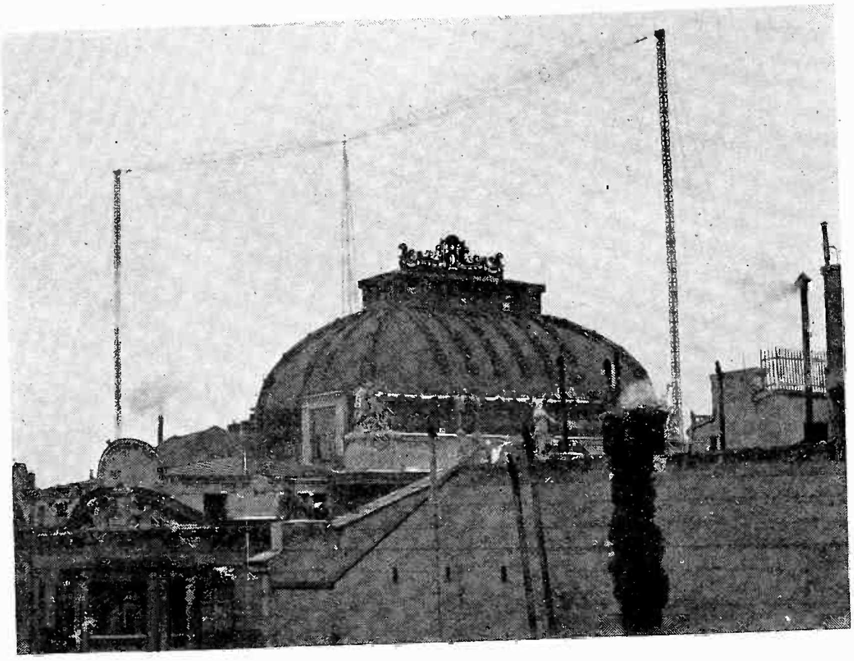
Wireless Telephony.

The first wireless telephonic communication in Norway was established between two experimental stations imported from England in 1920. These were installed at Oslo and Horten, and it was between these two places that speech by wireless was heard for the first time in Norway.

When in 1926 the Marconi Company constructed telephony stations for the use of whalers these were immediately introduced to the Norwegian whaling fleet, together with Marconi direction finding sets, and have since given excellent service. The Managers of the whale factory ships can now telephone to the various whale catchers of their fleet and by means of their wireless direction finders can determine the location of their vessels even in fog and in bad snowy weather.

The Norsk Marconikompani's head office and works are at Oslo, while it has a divisional office in the west of Norway at Bergen. The present Board of Management consists of Messrs. Otto Thoresen, shipowner of Oslo (Chairman), Laurietz Kloster, shipowner of Oslo, J. Bull, a mining manager at Horten, E. Skottun, Managing Director, with whom are associated Senatore Marconi and Mr. F. S. Hayburn, Deputy Managing Director of the Marconi International Marine Com munication Co., Ltd., of London.

A large number of letters have been received by the Norsk Marconikompani congratulating it on attaining its tenth anniversary, expressing appreciation of the important work it has carried out, and paying tribute to the leading position this Company holds in the Norwegian commercial world.



Aerials of the Belgrade Broadcasting Station

Belgrade Wireless Station.

A further report which has come to hand on the transmission of the new 9 kw. broadcasting station, erected by the Marconi Company in Belgrade, is worth recording. This is from Mr. Alfred Magri of Malta, who reports that with a valve receiving set he receives Belgrade much more clearly than other stations of greater power on the Continent of Europe. When he first heard the station announcing he said he could not think to what powerful station it belonged as he had hardly ever heard such a strong and powerful station calling. Both speech and music were exceptionally clear and strong in all instances, the passage from one key to another being perfect, and from beginning to end, talks, announcements and music being in perfect modulation.

Short Wave Broadcasting Transmitter for Italy.

The Italian Broadcasting Company has authorised the Marconi Company to proceed with the manufacture of a short wave broadcasting transmitter for Italy.

The Marconi Company has had considerable experience in the technique of short wave broadcasting through the operation of the short wave station (5 SW) at Chelmsford. The Italian Station will to a large extent follow the design of 5 SW and will enable the Italian Broadcasting Company to carry on a broadcasting service for the Italian Colonies.

Italy will thus be one of the first countries to make special provisions for its Colonies in its broadcasting organisation.

Communication with Belgian Colonies.

Another instance of the importance attached by European countries to direct wireless communication with their Colonies is the order just placed on the Marconi Company by the Société Belge Radioelectrique, on behalf of the Belgian Government, for a Short Wave Telegraph-Telephone transmitter which will be used for communication between Belgium and the Belgian Congo and Belgium and South America.

Two short-wave receivers of the latest type, similar to those used in the Marconi Beam stations, have also been ordered.