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Technical Editor: H. M. Dowsett, M.I.E.E., F.Inst.P., M.Inst.R.E.
General Editor: W. G. Richards.

A CHAPTER IN THE HISTORY OF THE MARCONI BEAM—II.

In Part I. of this article the position of affairs prior to the advent of the Marconi Beam system of communication was briefly reviewed and an account was given of the successful range trials of the experimental Short Wave Reflector plant at Poldhu carried out by Senatore Marconi on board the S.Y. "Elettra" in 1923-24.

The British Government contract for the construction of the Imperial Beam Stations followed. Since then the Marconi Beam system has definitely proved itself to be of immense value for Imperial communications.

The technical advances made in Short Wave Reflector transmission and reception up to the date of the signing of the contract were also described.

In Part II. of this article, given below, the further technical advances made up to the date of the opening of the first Imperial Beam Station are described, criticisms of the Marconi Beam system are discussed, and it is shown that certain suggestions which have been made for cheapening the standard Beam station equipment result in a loss of technical efficiency.

The Receivers.

THERE were two receivers, designed by Mr. Mathieu, in use on the "Elettra." The first of these, a copper-screened two-valve instrument, having a waverange of 40 to 100 metres, was used for signal intensity tests, and employed, as shown in the circuit diagram, Fig. 5, an aperiodic aerial, a detector valve with reaction, a tuned grid circuit with vernier condenser, a low pass filter to isolate the telephone circuit from reaction effects, a low frequency transformer and an audibility test circuit to which the telephone was connected. The test circuit consisted of an artificial line graduated in standard miles and providing a range of adjustment equivalent to 0 to 100 T.U.

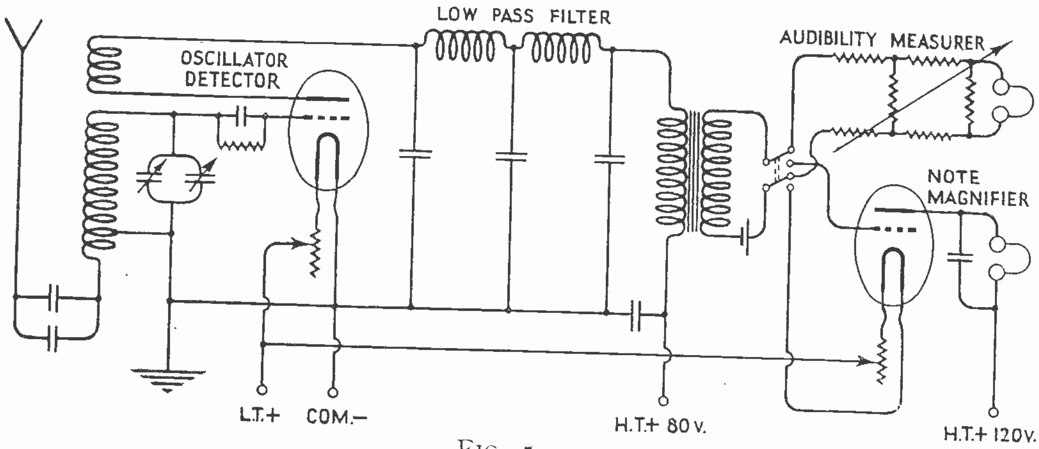

FIG. 5.

For normal reception the artificial line was switched off and an amplifying valve was used.

The second receiver was used to determine the type of instrument best suited for short wave traffic service, and comprised an aerial circuit, tuned intermediate circuit, a frequency changer circuit, two stages of sharply tuned high frequency amplification, and an autoheterodyne detecting valve, to which could be added two stages of low frequency amplification.

It was shown that sharp tuning would not do. To allow for wavelength wobble, filter circuits, suitable for passing narrow bands of frequency, and giving flat topped tuning, were required.

The Function of the S.Y. "Elettra."

A moving station possesses a great advantage over a fixed one whenever propagation problems are at issue.

If the transmission characteristics of the medium are unknown, a communication test between two or more fixed points will give data which can be used for the design of other stations at the same distance apart, but if one of them is mobile, the data collected can be expressed as an empirical law applicable to the design of stations at all intermediate distances, and within reasonable limits, to distances greater than that between the terminal stations.

Thus, the well-known Austin-Cohen formula for long wave propagation was deduced from the results of tests carried out between cruisers of the United States Navy and Brant Rock, and provided a reliable basis for long wave transmission calculations within known limits, and the tests between the "Elettra" and Poldhu had a similar character, as a very complete check was obtained, not only on signal strengths, but also on the width of the beam at different distances from Poldhu, and by providing many points on the distance-intensity curve removed the last vestige of doubt as to the effectiveness of the Beam at a distance.

By employing the "Elettra" the period of preliminary research necessary before a considered opinion could be given on the possibilities of the beam for world communications was shortened considerably, as a probability was turned into a certainty, and Senatore Marconi was therefore able to speak with absolute confidence of the future success of the system, which would not have been possible at this early date if the tests had been limited to communications between fixed stations.

The Long Wave Station at Rugby.

At this early stage of development, while no doubt remained that some sort of communication could be effected, the British Post Office could not be expected to be so optimistic as the Marconi Company about the commercial success of the Beam, and the construction of the high power long wave station at Rugby was therefore still proceeded with, its strategic value as a Broadcast Station being considered to be of first importance.

If the Beam stations were not successful, the risk was entirely that of the Marconi Company, and Great Britain would endeavour to send all her traffic by long wave; if they were successful, the Post Office would benefit, and the Beam service could be used to supplement the 24 hours' service which Rugby was expected to give.

Opinion, however, was otherwise in the Dominions; work on the high power long wave stations ceased, and, as a result of negotiations with the various Governments, the Marconi Company put in hand Beam stations for Canada, South Africa, Australia and India.

Continuation of Range Trials.

The range trials from Poldhu to the "Elettra" and to the listening posts all over the world were renewed in August, 1924, this time with the object of noting the effect of employing shorter wavelengths, transmission taking place on 15 kw. and with the aerial system and high frequency circuits altered from 92 metres to 60 metres, then to 47 metres, and finally to 32 metres, when, for the first time, it was definitely discovered that the daylight range increased very rapidly as the wavelength was reduced: New York, Rio and Buenos Ayres were finally able to receive when both terminal stations were in daylight; and Sydney, N.S.W., reported being able to read signals for 23½ hours out of the 24.

And so already research had revealed further useful features in short wave propagation, and had strengthened the confidence of the Marconi Company in the successful outcome of the Beam contract.

This concluded the preliminary transmission programme between Poldhu and the S.Y. "Elettra."

The research on short waves was continued at Chelmsford, and in October, 1925, using a plain half-wave aerial without reflector, it was found that a 15-metre wave, with only 200 watts to the aerial, was sufficient to give strong commercial signals at Buenos Ayres with the sun at its zenith on the great circle track, and before the first station was opened the Marconi Company had accumulated sufficient data by the aid of long distance tests to be able to determine the daylight absorption factor of all short wavelengths from 100 metres down to 10 metres, in addition to much information obtained by short distance tests of the behaviour of wavelengths from 15 metres down to 2 metres.

The actual dates when the Imperial Beam Stations were opened for service after completing their acceptance trials, were as follows :—

Transmitting Station.	Call Sign.	Wavelengths in Metres.	Receiving Station.	Date Service Opened.
Bodmin (England)	GBK	16·574 32·397	Yamachiche ... (Canada)	25th Oct., 1926.
Bodmin (England)	GBJ	16·146 34·013	Milnerton ... (South Africa)	5th July, 1927.
Grimsby (England) ...	GBH	25·906	Rockbank ... (Australia)	8th April, 1927.
Grimsby (England) ...	GBI	16·216 34·168	Dhond ... (India)	6th Sept., 1927.
Drummondville (Canada) ...	CG	16·501 32·128	Bridgwater ... (England)	25th Oct., 1926.
Drummondville (Canada) ...	CF	24·793	Rockbank ... (Australia)	16th June, 1928.
Klipheuval (South Africa)...	VNB	16·007 33·708	Bridgwater ... (England)	5th July, 1927.
Ballan (Australia)	VIZ	25·728	Skegness ... (England)	8th April, 1927.
Ballan (Australia)	VYZ	24·958 16·286	Yamachiche ... (Canada)	16th June, 1928.
Kirkee (India)	VWZ	34·483	Skegness ... (England)	6th Sept., 1927.

The Beam Service with Canada was to have been opened within six months after the sites of the transmitting and receiving stations had been chosen by the Post Office, but it was actually twelve months before this took place.

Research, development and erection work progressed together, the magnitude of the undertaking becoming more apparent as the practical details of design were worked out. The Post Office engineers being aware of the facts, agreed to the extension of the time limit as regrettable, but necessary and inevitable.

Later Progress.

The developments which occurred from the date when the contract was signed to the opening of the first Beam channel were as follows :—

The aerial was given its present design of a vertical sheet of separate aerials, each with its own feed. Phasing condensers then gave place to spiral phasing coils, and now, in order to reduce the reflection along the aerial wires which took place at these coils, they are made up in their present zig-zag form.

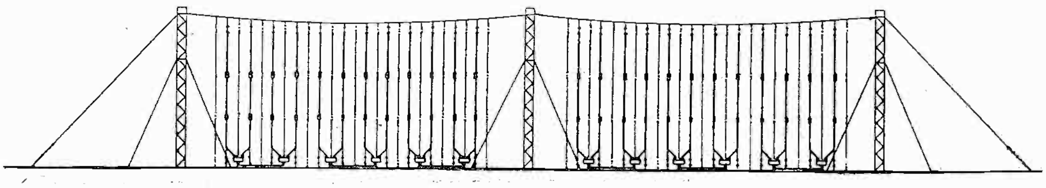

FIG. 6.

In the sketch elevation, Fig. 6, the terminals of the feeder system are shown connected to the bottom ends of the aerial wires, while the wires of the reflector, which are twice as numerous as those in the aerial, are shown in between.

The contract called for a 30° beam. The design of the Imperial Stations aerial systems provided a beam having a divergence of about 11°. Thus a very large increase in intensity was obtained above that originally proposed.

The parallel wire feeders became concentric air-spaced copper tubes fitted with expansion joints, the outer one earthed and the inner one making suitable tapping connections to screened transformers wherever a branch connection was required, and the length of the feeders to the individual aerials had to be compensated to make them all electrically equivalent.

As the best wavelength for each particular service had yet to be determined, the design of the transmitter was made as flexible as possible. The power to the anode of the magnifier was 20 kw., as used in the later " Elettra " tests, but instead of this circuit being controlled by a 6 kw. drive employing several valves in parallel, the set was made more stable, and the constancy of the wavelength brought better under control by reducing the drive power to about 100 watts, and employing one valve, three stages of magnification being then used instead of one, the circuits being of the balanced push-pull type, with single valves in each arm.

Crystal drives and tuning-fork drives were in use at that date, but they were not capable of frequency adjustment, and so a standard type of self-oscillator circuit was employed.

The wisdom of this has often since been demonstrated. Small, and sometimes large changes of wavelength were occasionally required in the preliminary tests, and the adaptability of the transmitter was a useful asset.

Originally designed to be adjustable to any wavelength found necessary from 60 metres to 20 metres, the transmitter was finally altered to cover the present waverange of 40 metres to 15 metres. The method of keying at Poldhu was by wave-change. To economise frequencies, the absorber valve method was introduced at the Imperial Stations.

The systematic transmission tests from Poldhu to various parts of the British Empire brought to light sufficient data to show that the best wavelength for a given channel depended not only on the position of the sun relative to the great circle through the communicating stations, but also on the distance and on the season of the year. Wavelengths of 20 to 30 metres are usually best suited for night transmission, and wavelengths of about 15 metres for daylight transmission. Every change of wavelength at the transmitter necessitated a change in the length of the aerial and reflector wires and phasing coils and a readjustment of the feeder circuit, and owing to the increase in the number of wires with smaller spacing which was employed with the shorter wavelengths, the large factor of safety which had been allowed for in the loading of the special self-supporting cantilever masts at the Imperial Stations was found to have been a useful safeguard.

The Marconi Short Wave Beam Receiver.

The reliability of a commercial service demands that the aerial shall pick up a strong signal, and this is provided at all the Beam receiving stations. This ensures that during the short fade periods the strength of the signal fluctuates, but is still considerable at its minimum value. The receiver then takes this signal and amplifies it, so that the maximum speed of working can be obtained at the trough of the short fade periods, and as the peaks of the signal currents do not enable the speed of working to be improved, they are therefore reduced by limiting circuits. The general scheme of the Marconi Beam receiver is shown in Fig. 7.

Short fading is less pronounced in a Marconi Beam service than a broadcast aerial service. This was to be expected if the assumption usually made is correct, that fading is due to the interference of rays which leave the transmitter at different zenithal angles, as any concentration in the vertical plane must reduce the interference possible when the rays which travel into the upper atmosphere are bent down again, and also there is less high angle radiation.

Short fading was also found to be supplemented periodically by complete fading at times of sunspot activity, when the great circles through the stations pass through or near the polar regions, this complete fading corresponding to magnetic storm disturbances experienced at the same time on the cables. Low latitude communications and long wave channels are much less subject to interruptions from this cause.

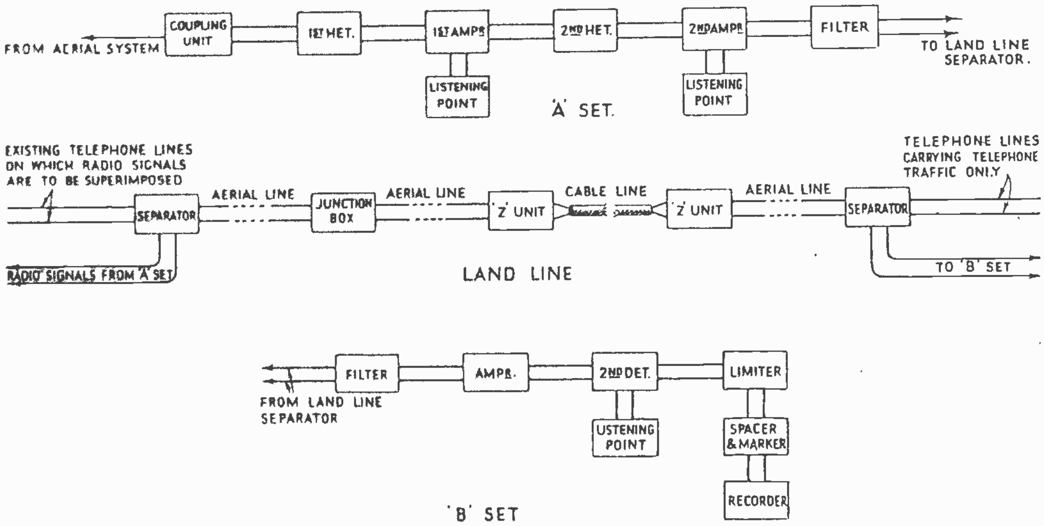

FIG. 7.

Interest Abroad in Progress of Beam System.

Competitors of the Marconi Company abroad had been watching with considerable interest, but some business scepticism, the progress, first of the Beam researches, and, later, the development of the Beam stations, under the impression that they were about to witness a scientific experiment carried out on a very large scale, but one which involved so many unknown and variable factors that commercial success was very doubtful.

The unexpected, however, happened, and they awoke to the sudden realisation that not only was a world-wide Beam network in being and doing profitable business, but the future of radio communications was bound up with the extended development of the Beam principle, and they were years behind the Marconi Company in the new technique.

Broadcast traffic transmission was wasteful, and limited the number of possible channels, and for ultra short waves, to which attention is now being directed, the dimensions of aerials and reflectors are so much smaller that the factor of cost is no longer a formidable item.

These firms have therefore now entered this field of development, and have devised beam aerial systems which copy in principle the Marconi-Franklin model, but differ from this model in certain important technical features, which it is claimed allow the cost to be considerably reduced.

It will be instructive to examine some of these methods for producing a cheaper short wave beam, as they also result in a sacrifice of technical efficiency.

At first arguments were brought forward to discount the value of directive radiation. Critics of the Beam system contended that as energy tends to an average throughout the radiated wave, so that inequalities in the wavefront fill up, the beam as it travels further would become more diffuse, so that at a great distance it would show no concentration, and that the action of the refracting layers would certainly encourage this.

There were some tests also made in Germany with a horizontal reflector, which appeared to confirm this view until further information came to hand which explained the results, for it was found that the dimensions of the reflector relative to the aerial were such that the radiation propagated was widely dispersed at the source, at no time did it possess true beam concentration, and the zenithal angle at which the main radiation left the aerial was very different to what had been assumed.

The results of a long series of careful direction finding tests go to show that vertically polarised radiation leaves the Marconi-Franklin Aerial Reflector system inclined at a zenithal angle of about 15° to the horizontal, that within the region of the skip distance the radiation is mainly passing overhead in the Heaviside layer, but below this layer it is scattered ; also that beyond the skip region the radiation once more attains a directional character giving a great circle bearing, and strikes the receiving aerial at a small zenithal angle.

Strong Signals Required for High Speed Working.

The next argument was that aerials and reflectors were larger than was actually required.

We have learnt that very little power is necessary to reach to the ends of the earth on a suitable short wave, but that to work at high speed requires strong signals.

While it was possible to communicate at under 50 words a minute from Germany to South America, and also from France to West Africa and South America with types of beam aerial having much less area than used at the Imperial Beam Stations, on account of which a saving in cost was claimed, these smaller aerials denoted that the beams produced had a wider spread of radiation, which resulted in weaker signals at the receiver and a slower speed of working.

There is no service anywhere in the world which can work at so high a speed as the Marconi Beam Stations, a record which has not been approached since they were opened two years ago, and it is interesting to note that our competitors, in order to obtain signals of the requisite strength and dependability for commercial service, are now increasing the area of their aerials to approach nearer to the standard which the Marconi Company established when the Imperial Beam Stations were erected.

The separate feed to each vertical wire of the Franklin aerial is elaborate but very efficient, and where cost must be considered, it is natural to enquire whether a simplified and cheaper system could not be devised.

Suppose the aerial wires were fed from the transmitter in groups instead of individually, what would be the result ?

The feeder itself would cost less, but the aerial would cost more, as in order to obtain an even distribution of current throughout the network, the aerial end would have to be complicated by the addition of a special phasing unit in each wire of the group, having a value graduated to the distance from the feeding point. Also, as the adjustment of these phasing units is correct for one frequency only, any slight change in wavelength would immediately upset the balance of current throughout the aerial, and the concentration of the beam would alter.

If phasing units were not employed, the radiation would be so diffuse that, although it would have direction, it could no longer be described as a beam.

Types of Projector Aerials.

In recent American and French designs of projector aerials, rectangular and lozenge-shaped networks have been employed, which are broken up by insulators so as to constitute several groups of half-wave aerials in series, suspended one above the other, and these groups are fed either from one end or from the middle.

A cheaper feeder system is in consequence obtained, but the character of the beam is again adversely affected.

The current in the network, instead of being evenly distributed, is greatest near the feeding point ; if this is at the end the beam will not be at right angles to the plane of the aerial, if it is at the middle, the direction will be correct, but the beam will have a wide angle, and in both cases any slight change in the frequency of the transmitter will cause the beam to swing away from the correct direction.

The Franklin method of feeding the aerial does not introduce this trouble; if the frequency alters, the intensity of the beam is affected, but its direction and concentration do not change, so that the cost of the feeder system is fully justified.

It has been asked whether the success of the Beam system, as such, is mainly due to the good qualities of the transmitter, the efficiency of the transmitting aerial and reflector as a beam producer, the effectiveness of the aerial and reflector at the receiving end as a collector of energy over a wide area, or to the excellence of the receiver.

Would it be possible, for instance, to replace any part of the installation with something less elaborate and cheaper, and still get very nearly the same result?

The reply is, that each section of the system contributes a substantial quota to the total.

The system was developed as a whole, and if only part of the equipment were used the efficiency of the complete design would disappear, and any reduction in first cost would soon be more than offset by the fall in the traffic returns due to a less reliable service and a slower speed of working.

Present Position of Imperial Beam Services.

The Cable and Wireless services of Great Britain and the Dominions are now at the point of merging their interests.

With a common centre for Imperial and foreign communications at the heart of the Empire, the creative energy of the new composite organisation which is being formed, can be devoted without stint to the actual business of traffic expansion along existing channels, and to the economic development of new channels; the stimulus of foreign competition ensuring that nothing less than the best and most up-to-date equipment will survive and be employed in the operation of these public world communication services.

H.M.D.

A DESCRIPTION OF THE BRATISLAVA BROADCAST TRANSMITTER

MARCONI TYPE P.A.5

Czecho Slovakia occupies a very favourable position for broadcasting in the heart of Europe. The area of the Republic is about 150,000 sq. kilometres and is therefore roughly as large as Great Britain. Its population, which includes several distinct races, is approximately fourteen millions.

The first steps towards broadcasting in Czecho Slovakia were taken in 1923 and since then rapid strides have been made towards a well organised and efficient broadcasting service.

When all the projected stations are completed, Czecho Slovakia will be entirely independent as regards the transmission of Central European news to its own nationals, it will be in a position to broadcast in the best manner possible to overcome the language difficulty, and its own news will be more widely distributed to foreign countries.

Of the chain of five stations projected to complete the Czecho Slovakian Broadcasting Organisation, the new high power station to be erected shortly at Bratislava, situated on the Danube and the Austrian border, will be the largest and will function in very much the same way as Daventry does in Great Britain.

A description of the Bratislava transmitter which illustrates a new departure in design is given below.

THE transmitter to be described below is one of a series developed by the Marconi Company with a view to providing broadcast transmissions of high quality and conforming in every respect to the technical requirements of modern practice.

The simpler types of transmitters consisting of a modulated self oscillator, or a drive and single magnifier, although having given, and in fact continuing to give excellent service, are not now considered quite adequate in certain respects, and more complicated sets are called for to cope with present day conditions.

In the design under review particular attention has been given to the following points :—

(A) Great constancy of wavelength independently of the regulation of the supply mains.

(B) Complete freedom from any frequency change of the carrier wave due to modulation.

(C) Deep modulation without distortion.

(D) A straight line frequency characteristic throughout the useful audio-range.

(E) Freedom from harmonic radiation.

(F) Adjustability to any wavelength within the authorised broadcast band (200-545 metres, 1,500 to 550 K.C.).

(G) Compactness, together with adaptability to various lay-out arrangements, in order to suit differences in shape and size of the accommodation space.

The particular set to be described has been ordered from the Marconi Company by the Broadcasting Organisation of Czecho Slovakia and will be erected at Bratislava to replace the small power transmitter at present serving the locality. The wavelength allotted is 300 m. This transmitter is rated at 12 kw. carrier energy, and is designed for linear modulation up to 80 per cent., so that at full modulation the aerial power amounts to 15.8 kw.

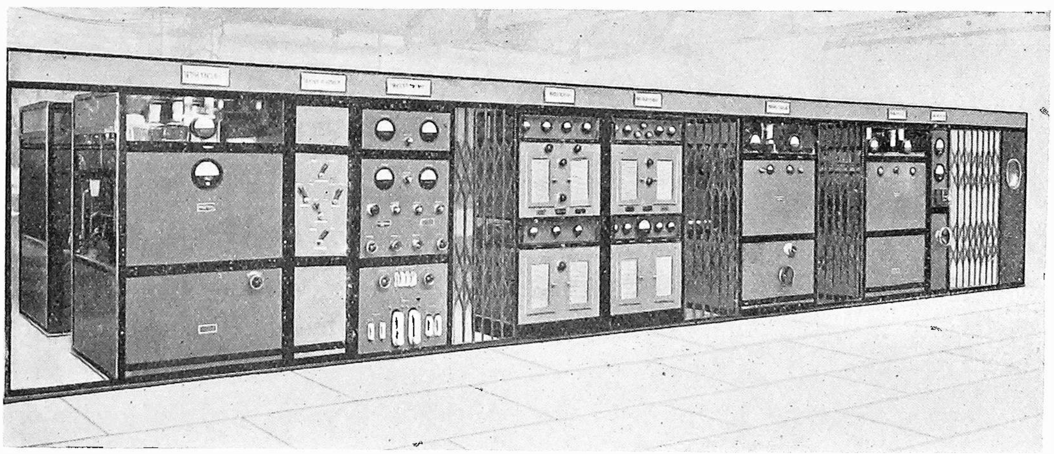

FIG. 1.

The transmitter proper (Fig. 1) comprises seven independent units, namely :—

1. Drive Unit.
2. Modulated Amplifier Unit.

3. Intermediate Amplifier Unit.
4. Power Amplifier Unit.
5. High Frequency Unit.
6. Harmonic Filter Unit.
7. Feeder-Aerial Coupling Unit.

A description of these units in detail will enable a clear idea of the design to be obtained.

1.—The Drive Unit.

This consists of two completely shielded stages, the drive and the isolator, each complete with high frequency circuits and mounted in one framework. The drive uses two valves, Type DET. 1, the filaments of which are supplied from an accumulator battery, and the anode voltage is provided by a one thousand volts motor generator driven by the same accumulator.

This arrangement renders the drive frequency completely independent of any fluctuations in the power mains, and makes possible a very high degree of constancy. Any wavelength between 200 and 545 metres is available by adjustment of the tuning condensers and inductances. The drive is inductively coupled to the isolator by variable coupling coils tuned by a variable condenser.

The valve used for the isolator is one T. 250A, which takes its filament supply from the main filament lighting D.C. dynamo. The anode voltage for this valve comes from the 3,000 v. machine, which also feeds the modulated amplifier unit.

The isolator circuit is neutralized, and the valve is provided with a negative bias so adjusted that no grid current flows, in order that the load on the drive shall remain constant.

The isolator is directly coupled to the succeeding stage (Modulated Amplifier) by means of a variable tapping on the anode tuning coil.

2.—The Modulated Amplifier Unit.

This unit consists of two shielded stages mounted in one framework of similar dimensions to the Drive Unit. One case mounts the modulated amplifier with its high frequency oscillatory circuit, and the other the modulator and sub-modulator together with the speech choke, coupling resistances, etc.

The valve used for the modulated amplifier is one DET. 3 with D.C. machine filament lighting. The working anode voltage is approximately 1,250 volts, the 3,000 volt supply being reduced by a resistance shunted by a large condenser to byepass the audio-frequency component.

with a twin rectifying unit consisting of six water cooled valves, Type CAR.2, the filaments of these being heated by suitable step down transformers from the three phase mains. A combination of iron cored chokes and paper dielectric condensers filters out the alternating current ripple, and a condenser of ten microfarads capacity terminates the smoothing circuit providing a low impedance bye-pass to the lower audio frequencies. The supply for the preliminary stages comes from a three thousand volt D.C. motor dynamo, or more accurately from two separate fifteen hundred volt dynamos connected in series. This supply also has a condenser of ten microfarads across it for the same reasons as mentioned previously. As previously explained the drive has its own battery supply for reasons of frequency stability.

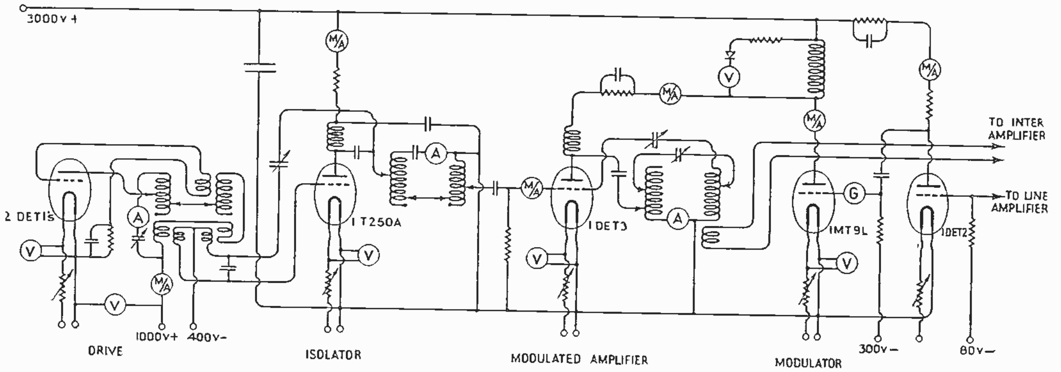

FIG. 3.

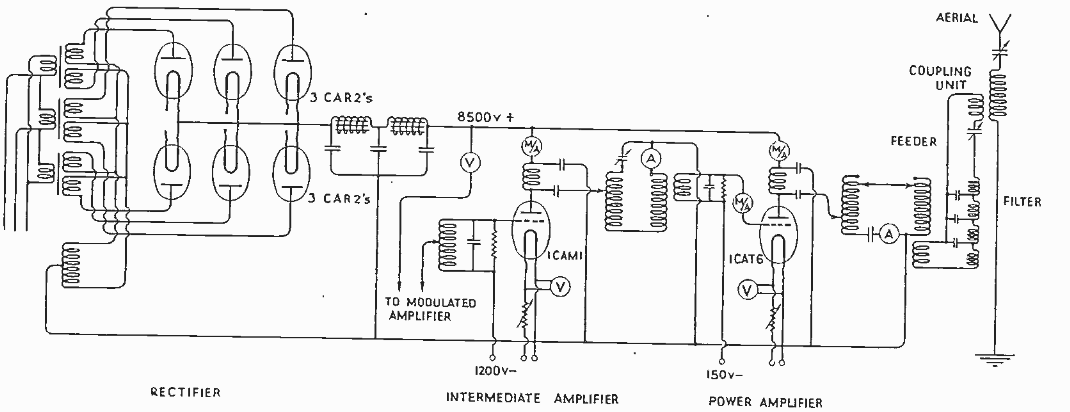

FIG. 4.

The various starter switches, field rheostats, etc., are grouped on a control panel, in order that the set may be operated conveniently from a fixed point. Control of the voltage of the main high tension supply is carried out by adjusting the filament temperature of the rectifiers, permitting adjustment from full voltage to about one quarter the normal. With water cooled rectifying valves this forms a convenient and economical method of adjustment.

The audio control and monitoring equipment comprises resistance-capacity coupled amplifiers with arrangements for maintaining the input to the transmitter at any desired level. A high quality check receiver and Marconi moving coil speaker, with connections for throwing either direct to the incoming line or to radio enables the quality of the transmission to be observed. The power relations between the various stages are approximately as follows, taking the anode inputs in each case in the carrier condition.

Drive	100 watts
Isolator	150 ,,
Modulated Amplifier	125 ,,
Modulator	360 ,,
Intermediate Amplifier	4 kw.
Power Amplifier	36 kw.

An overall frequency characteristic of the transmitter is shown in Fig. 1, from which it will be observed that the modulation is well maintained at both ends of the audio scale.

A theoretical diagram of connections is given in Figs. 3 and 4, although to avoid undue complications the power supply circuits are not included.

These two diagrams are to be read in conjunction with one another and represent together the complete diagram of connections of the transmitter.

W. T. DITCHAM.

A DISCUSSION ON SHORT WAVE FADING—II

It has been already suggested, in the preceding section of this paper, that S.W. fading should be considered under two heads—

(1) *The Short Fading of a minute to fractions of a second.*

(2) *The Long Fading of, perhaps, days at a time.*

A brief theory has been formulated as to the causes of these two types of fading, from which it seems that the short fades are occasioned by reflection, etc., from the Heaviside layer, and that the long fades are attributable to magnetic storms.

Curves have been taken of the variation of intensity of signals with time, and an attempt has been made to calculate the variability of such a curve in the case of two rays statistically independent, and in the case of n rays.

By comparing these values of variability with observed values some information has been gained as to the type of rays whose interference produces fading of the first class.

Fading of the second class may possibly be eliminated by the use of varying wave-lengths to suit conditions.

Spaced Aerials.

VARIOUS devices for the elimination of fading have been considered, in particular the combination of the rectified signals from two fairly widely separated aerials.

It is an undoubted fact that the fading curves of two widely spaced aerials are entirely different, and if the signals from these two are added without regard to phase, a very considerable improvement might accrue.

There has been very considerable divergence of opinion as to the distance of separation necessary to produce results.

The Dutch experimenters have considered that a distance of 30 feet was sufficient to give marked differences in the fading curves, while those who have experimented on the subject in this Company are convinced that many wavelengths separation is necessary before any appreciable results can be obtained.

If the results are due to interference, the minimum distance apart of a maximum and minimum can only be $\frac{1}{4}\lambda$ in the very unlikely case where the two interfering rays are travelling in opposite directions. Again, if the two receivers are placed in a line at right angles to the ray, then the variation per wavelength along this line cannot be a large percentage of the mean value if the ray maintains its coherence.

For did such a large variation exist, it would imply a magnetic force in the direction of the ray, which, combined with the vertical electric force, would produce an energy flow at right angles to the ray and disperse it. Since all observations with a direction finder indicate a well-defined ray, such a state of affairs is not possible, and we may conclude that along the wave front the intensity must be constant over many wavelengths.

The conclusion may be drawn that many wavelengths' separation is required, and that it is best to place the receivers along the direction of the ray, rather than along the wave front. It is, however, possible to have different fading curves on two aerials at the same place if the aerials are different. For example, if one is vertical and the other horizontal and at right angles to the ray.

The behaviour of the signals on an ordinary frame aerial immediately show this possibility. For the existence of a wandering minimum, which occurs under certain circumstances, shows that the ratio of the horizontally polarised to the vertically polarised electric force is varying from time to time, and that therefore the fading curve for a horizontal and vertical aerial, or for two mutually perpendicular frames (one in the plane and one perpendicular to the plane of the rays) must be different.

Unfortunately this type of reception is more common for relatively short distance transmission (and is most prevalent just outside the skip distance) and is relatively rare at long distances (where the fading eliminator is mostly required) where the horizontal electric force is generally so small as to be insufficient for combining purposes. Nevertheless, it may be a method worth trying.

Theoretical Gain with Spaced Aerials.

It is possible to calculate the expectation of gain on using two spaced aerials on the assumption that these are so far apart that the resultant E.M.F. at the one aerial can be considered to be statistically independent of the resultant at the other aerial, or, to go further, we can include any degree of correlation between the two. To take the simpler case first: let r be the resultant at one aerial, and r^1 be the resultant at the other, then if r and r^1 are independent, the probability that r lies between r and $r + dr$ and that r^1 lies between r^1 and $r^1 + dr^1$ is

$$\frac{1}{\pi^2}\cdot\frac{dr}{\sqrt{1-\frac{r^2}{4}}}\cdot\frac{dr^1}{\sqrt{1-\frac{(r^1)^2}{4}}}$$

in the case of two rays interfering, or $\frac{4}{n^2}e^{-r^2/n}\cdot rdre^{-(r^1)^2/n}r^1dr^1$ in the case of n rays.

The mean square values of (r, r^1) are in the two cases :—

$$\frac{1}{\pi^2}\int_0^2\frac{dr}{\sqrt{1-r^2}}\cdot\int_0^2\frac{dr^1}{\sqrt{1-(r^1)^2}}\cdot(r-r^1)^2$$

and $$\frac{4}{n^2}\int_0^\infty e^{-r^2/n}\cdot rdr\cdot\int_0^\infty e^{-(r^1)^2/n}\cdot r^1\,dr^1(r+r^1)^2$$

which can be shown to be respectively $4\left(1+\frac{2}{\pi^2}\right)$ and $n\left(2+\frac{\pi}{2}\right)$.

If r and r^1 had not been added independent of phase, the resultants would have been 4 and 2n respectively, so that, in general, adding the two, independent of phase (phase splitting), results in an increased mean square intensity in the ratio $\left(1+\frac{2}{\pi^2}\right)$ and $\left(1+\frac{\pi}{4}\right)$ respectively in the two cases. That such an increase should occur is obvious, for adding independent of phase avoids those occasions when the two sets might interfere by phase opposition. We can now calculate the mean square variation thus in the two cases ;

it is $$\frac{1}{\pi^2}\int_0^2\frac{dr}{\sqrt{1-\frac{r^2}{4}}}\int_0^2\frac{dr^1}{\sqrt{1-\frac{(r^1)^2}{4}}}\cdot(r+r^1-2\sqrt{k_1})^2=x_1\text{, say,}$$

or $$\frac{4}{n^2}\int_0^\infty rdre^{-r^2/n}\int^\infty r^1dr^1e^{-(r^1)^2/n}(r+r^1-\sqrt{k_2\,n})^2=x_2\text{, say,}$$

where $$k_1=\left(1+\frac{2}{\pi^2}\right)\text{ and }k_2=\left(2+\frac{\pi}{2}\right).$$

We find as a result

$$x_1=4k_1\left(2-\frac{4}{\sqrt{k_1\pi}}\right)$$

$$x_2=2k_2n\left(1-\sqrt{\frac{\pi}{k_2}}\right)$$

and dividing by the mean square value in each case to get the percentage variability.

These are : $2\left(1-\frac{8}{\sqrt{k_1\pi}}\right)=0{\cdot}105$

and $2\left(1-\sqrt{\frac{\pi}{k_2}}\right)=0{\cdot}125$

The percentage variability is reduced in the two cases as was to be expected; the reduction of variability in the first case is from 0·200 to 0·105, and in the second case from 0·228 to 0·125. The gain in both cases is to reduce the variability to nearly half.

But perhaps it is not quite fair to take the reduction in variability as the only gain. Where the process of limiting can be resorted to, it is only the occasions when the strength is reduced below a certain limiting value which are likely to be troublesome, so we should compare the probabilities that the strength is less than a definite fraction of the whole in the two cases. Thus the probability that the resultant is less than x is

$$\frac{1}{\pi}\int_0^x \frac{dr}{\sqrt{1-\frac{r^2}{4}}} = \frac{1}{\pi}\sin^{-1}\frac{x}{2} \qquad \text{(in the two-ray case)}$$

in the second case, where the two results are added independent of phase, it is:

$$\frac{1}{\pi^2}\int_0^x \frac{dr}{\sqrt{1-\frac{r^2}{4}}}\int_0^{x-r}\frac{dr^1}{\sqrt{1-\frac{(r^1)^2}{4}}}$$

$$= \frac{1}{\pi}\int_0^x \frac{dr}{\sqrt{1-\frac{r^2}{4}}}\cdot\sin^{-1}\frac{x-r}{2} \simeq \frac{x}{2\pi^2}\cdot\sin^{-1}\frac{x}{2} - \frac{2}{\pi^2}\left(\frac{\sqrt{1-x^2}}{4} - 1\right)$$

which, when x is small, is nearly $\frac{x}{2\pi^2}\left(\sin\frac{x}{2} - \frac{x}{2}\right)$ and is a very small quantity compared with $\frac{1}{\pi}\sin^{-1}x$

The gain here is very large, and increases in proportion as the limiting signal x (compared with the main signal) is reduced.

Noise level.

In this no account is taken of noise level which fixes the limiting value of x; on adding the signals from the two aerials the noise level is increased probably about two-fold, so that possibly the limiting value in the second case ought to be 2x, and the corresponding probability

$$\frac{x}{\pi^2}(\sin^{-1}x - x)$$

It is impossible, without a knowledge of the limiting value x, to estimate what the gain will be; taking $\frac{x}{2}$ equal to $\frac{1}{10}$, then the reduction in probability will be 1·15 to 1,000. That is, if there were 1,000 interruptions in a programme in the first case due to the signal fading below noise level, there should only be one in the latter case. This seems too good to be true, and the excellence of the result may

only be due to the approximate nature of the formula, but in any case it is certain that the improvement must be greater than 30 to 1.

In the second case, where there are a large number of vectors, the probability that the resultant on one aerial shall be less than x say, is

$$\frac{2}{n}\int_0^x e^{-r^2/n}\cdot r\,dr = \left(1 - e^{-x^2/n}\right)$$

the probability that the resultant from the two aerials shall be less than x is:

$$\frac{4}{n^2}\int_0^x e^{-r^2/n}\cdot r\,dr \int_0^{x-r} e^{-(r^1)^2/n}\cdot r^1\,dr^1$$

This cannot be evaluated in finite terms, but when $\frac{x^2}{n}$ is small, as it always is, this may be expressed in the form

$$1 - e^{-x^2/n}\left\{1 + \frac{x^2}{n} - \frac{x^4}{4n^2} + \frac{x^6}{15n^3} \cdots\cdots\right\}$$

in the case where $\frac{x^2}{n} = \frac{1}{10}$, *i.e.*, where the amplitude fades down to $\frac{1}{3.16}$ of its RMS value.

The probability of a fade less than this value is reduced from 0·095166 to 0·00555, or practically 17 fold. For smaller values of x the gain is proportionally greater.

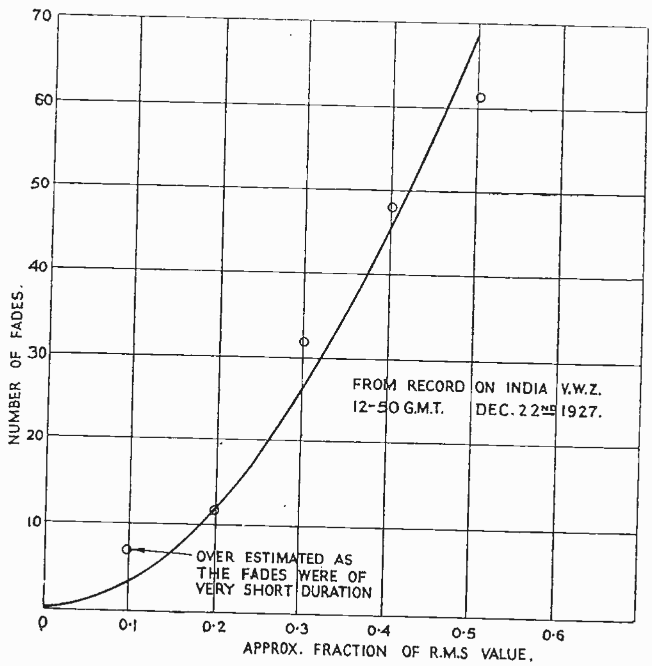

FIG. 3.

According to the probability theory, the number of fades below a given value ϵ should be nearly proportional to ϵ^2 when ϵ is small.

The curve, shown in Fig. 5, taken from an observed record, illustrates this. It will be seen that this law is a fair approximation to the results.

When this is the case, the theory given for the gain of two aerials over one is very fairly correct. This can be extended to three or more aerials, and it is found that the gain in using three aerials over using two is at least as great as the gain of two over one.

There should, therefore, be a very considerable gain by using as many aerials as possible, so long as these are far enough apart that the received signals in each are statistically independent.

There is no doubt that the object to achieve is to get as great a ratio of signal to noise level as possible in each aerial, and then combine all the E.M.F.'s of the two aerials are statistically independent.

T. L. ECKERSLEY.

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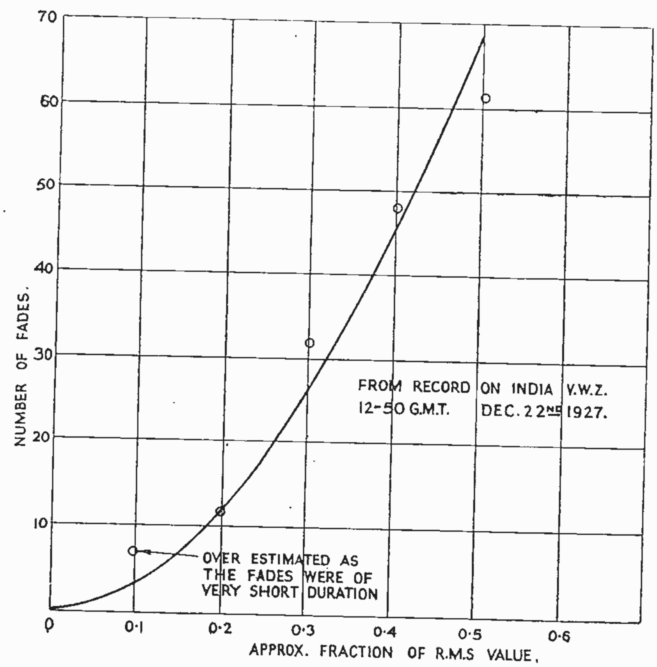

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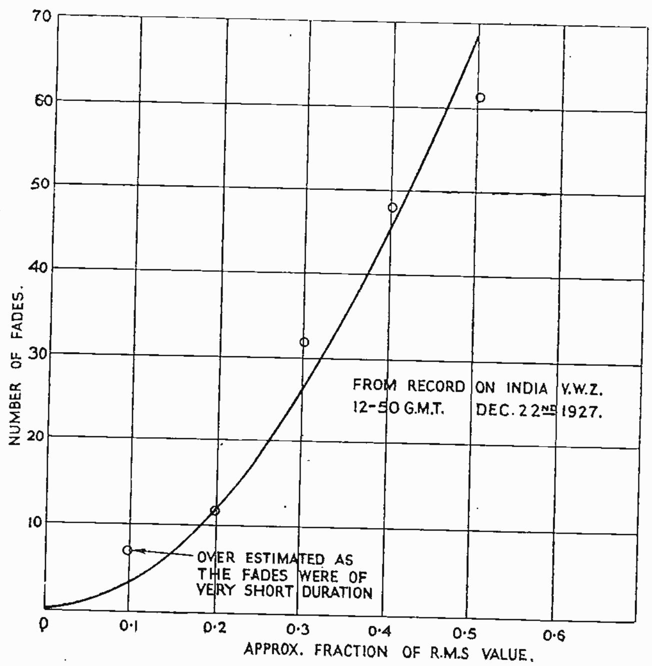

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MARCONI LONG WAVE SHIELDED VALVE RECEIVERS

TYPES R.g.18 and 19

The technical requirements demanded of a modern naval receiver are of a very high order, and it was with a view to supplying this demand that the Marconi Company devoted unusual attention to the design of the R.g.18 and R.g.19 receivers for naval, military and general purposes.

Particular points to which attention has been devoted is their efficient operation over a wide range of wavelengths and control by a minimum number of tuning handles.

An unusual degree of selectivity and amplification has been obtained by the use of screened grid Marconi valves to give two stages of high frequency magnification.

The complete R.g.19 receiver weighs approximately 160 *lbs.* (75 *kilos.*), *and has overall dimensions of* 35 *by* 20 *by* 11 *ins.* (90 *by* 51 *by* 28 *cms.*), *and the R.g.18 receiver weighs* 70 *lbs.* (32 *kilos.*), *and measures* 34 *by* 12 *by* 11 *ins.* (87 *by* 29 *by* 28 *cms.*).

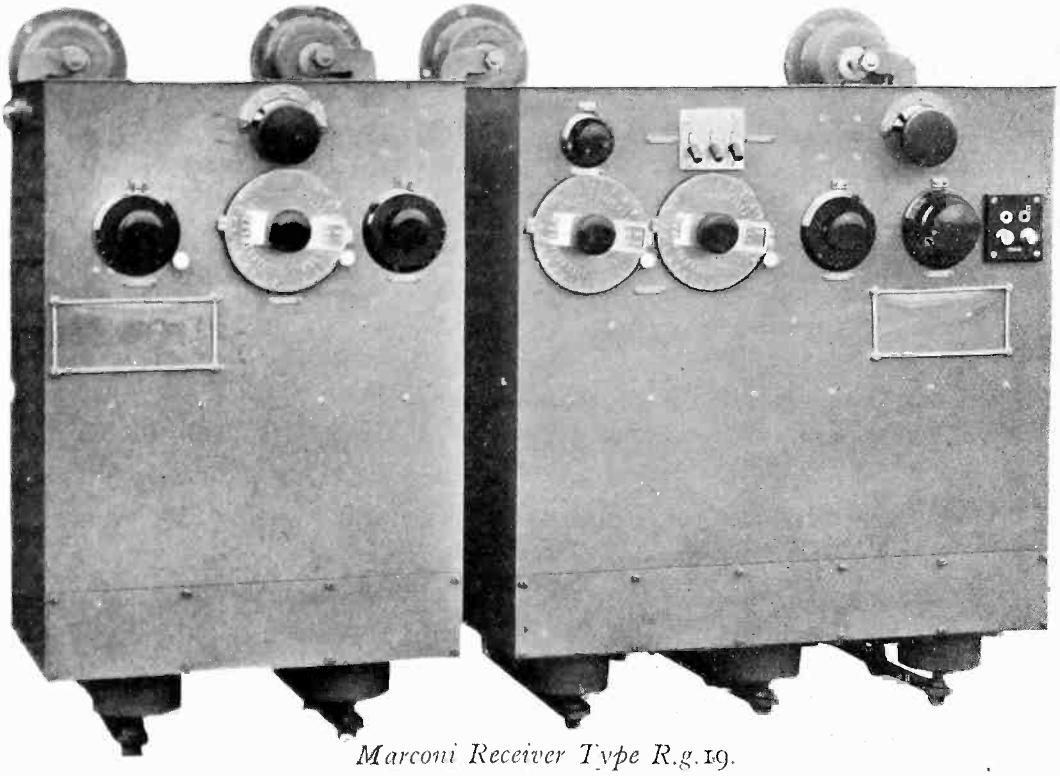
AS the R.g.18 and R.g.19 receivers differ from each other only slightly in design, it will be sufficient to describe in detail the R.g.19 receiver, and to indicate in what respects the R.g.18 receiver differs from it.

Both of these receivers were designed for use on warships, where space is, of course, a major consideration. It will be appreciated, therefore, that some deviation from ideal construction was necessary in order to limit the space occupied by the receiver.

The R.g.19 receiver is made in three editions at present, each comprising two essential components—the tuner and the amplifier. These two are enclosed in separate brass boxes, very efficiently screened and supported by rubber shock absorbing devices. The three editions cover the following waveranges :—

R.g.19	600—24,000 metres.
R.g.19a	300—10,000 metres.
R.g.19c	500—22,000 metres.

It will be seen from the above that the waverange of the sets is very large indeed, four separate ranges being provided on each receiver to cover this waverange.



Marconi Receiver Type R.g.19.

The four ranges are obtained by the use of ganged barrel switches, operated from the front of the receiver, which connect the various coils required. All the tuning condensers are provided with four scales, one for each range, as indicated by coloured pointers which correspond to the colours of the barrel switches.

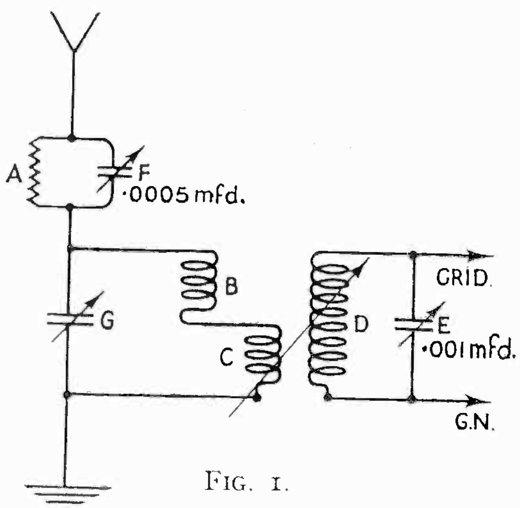


FIG. 1.

A simplified diagram of the tuner is given (Fig. 1). The two condensers, F and G, have their moving vanes actuated by the same spindle but isolated from each other. G tunes the aerial inductance consisting of coils B and C, and F is simply the coupling condenser from the aerial. It is made variable with G to ensure correct coupling at all wavelengths. A static leak A is provided across F to prevent any charge building up across the condenser. The first closed circuit consists of the inductance D and the condenser E, from which the input is taken to the first high frequency valve.

The amplifier is contained in a separate box, as stated above. It consists of two screened grid high frequency valves, an anode bend detector, a fourth valve which can be used as a note filter or an ordinary transformer coupled stage of audio-frequency magnification or cut out altogether by means of switching, and a fifth valve which can be used as a local oscillator for continuous wave reception.

A simplified diagram of connections of the complete amplifier is given below (Fig. 2).

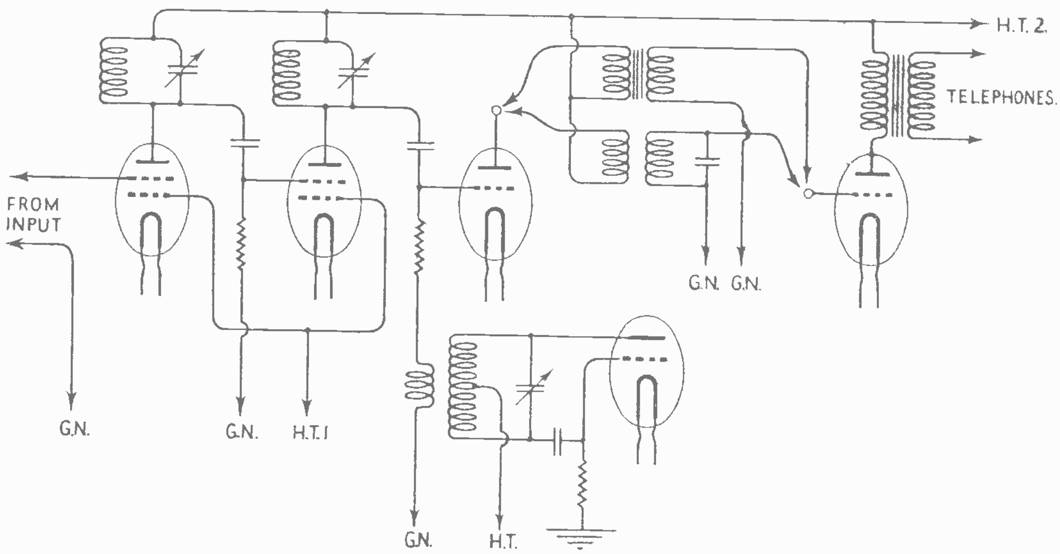


FIG. 2.

It will be seen from the above that the two stages of high frequency magnification are tuned-anode coupled, the two inductances for the tuned anodes being changed by means of the range switches. They are tuned by means of two .001 mfd. variable condensers which are provided (as are also the aerial condensers) with a quick search device to enable a band of about 10 per cent. either side of a spot wave to be searched quickly. This feature makes reception of a station remarkably easy as there are only two controls necessary to be handled.

It will be hardly necessary here to explain the action of the screened grid valves in full detail, although a short explanation may prove beneficial.

The disadvantage of the ordinary triode for high frequency work is the reaction which may occur through the capacity existing between the grid and anode of the valve. This capacity is too small to be of any importance in low frequency amplification, but it produces unwanted reaction effects and oscillations in high frequency circuits. Many schemes have been put forward to balance out this capacity effect, such as neutrodyning, etc., which were more or less successful. In the Marconi screened grid valve this unwanted capacity is eliminated by an extra grid which is placed between the control grid and the anode and is earthed as far as high frequency is concerned. It cannot be earthed directly as it would prevent any electrons reaching the plate, therefore a positive potential is applied to this extra grid to draw electrons through to the plate.

The characteristic curve of such a valve would be as indicated below (Fig. 3).

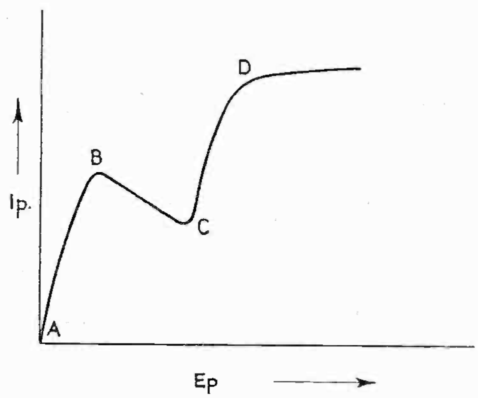


FIG. 3.

From A to B the curve represents a rapid increase of plate current with plate potential, from B to C the current decreases as the voltage rises, due to the fact that new electrons are produced at the plate by electronic bombardment and are pulled back to the outer grid. From C to D this current becomes positive again since now the plate potential is high enough to prevent electrons being dragged back to the outer grid, and from D onwards, no matter how we increase E_p, only a very small increase of I_p will be produced since the saturation current of the valve has been reached.

A study of the characteristics of such a valve will show that we have a valve capable of very high magnification as well as possessing no appreciable grid-anode capacity. With an anode voltage of 120 v. and an outer grid voltage of 80 v. a valve magnification factor of approximately 110 is obtained.

It is essential in any shielded grid valve set that the screening of the coils, etc., should be very efficient if high magnification is to be obtained, and this fact is paid strict attention to in the design of the R.g.18 and 19 receivers.

The screened grid valve then gives considerably more magnification per stage than it is possible to obtain with the triode, and also is exceedingly stable in its action. It is possible, by using suitable circuits in cascade, to effect a tremendous amplification of high frequency signals by the use of these valves, whilst still keeping the whole amplifier well away from oscillation.

The tuned anode method of amplification is by far the most suitable method of high frequency amplification to use in such a receiver as the R.g.19 on account of the fact that to alter the range, only one coil needs to be changed in each stage, although the overall magnification per stage is slightly less than would be obtained from a stage of transformer coupled magnification.

The amplified high frequency signal is then rectified by an anode bend rectifier, which is chosen because it is less liable to grid blocking through very strong signals or static. In series with the grid circuit of this rectifier, and tightly coupled to the inductance of the local oscillator, is the coupling coil to this oscillator.

For C.W. reception a separate oscillator is used, consisting of a coil with grid and plate tappings tuned by a .001 variable condenser. The former for this coil, which also supports the coupling coil to the detector, is changed for the various ranges by means of the range switch, and a calibration chart is supplied with the receiver for the condenser settings for each range. This condenser is provided with a vernier movement to enable extreme accuracy of adjustment to be made.

The next valve, as has been stated above, can be used either as a note filter or a stage of transformer coupled amplification. The note filter is arranged on the tuned grid principle and the circuit is as below (Fig. 4).

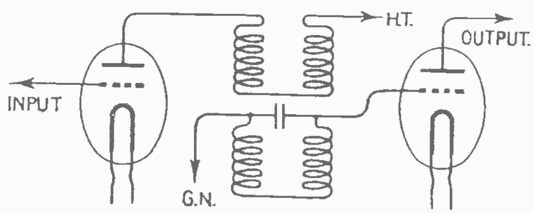


FIG. 4.

Both the grid coil and the anode coil are divided in half and connected astatically. The grid and anode coils are then coupled in such a manner as to make the sense of each set the same. The anode coils are closely coupled to the grid coils and the whole circuit is tuned accurately to 1,200 ∿ by means of a fixed condenser of .01 mfds. capacity. The resonance curve of the filter is very sharp, and the receiver relies upon this filter for its selectivity on C.W. to a large extent. More will be said on this point later, however.

When the valve is used as an audio-transformer coupled stage, an ordinary iron core transformer with a ratio of approximately 4 : 1 is used, and no special description of its action need be given here.

The set is designed for use with low resistance telephones, and the output from the last valve is taken to a telephone transformer.

In the case of the R.g.19 series the short wave coils are wound with stranded wire and are very low damped. As the wavelength of the coils increase, however, space does not permit such an ideal design of coil, and the damping of the coil increases, resulting in a slightly less efficiency of high frequency magnification. This effect is most marked on the fourth range, where coils of very high inductance have to be confined to very small dimensions. It should be clearly understood, however, that the selectivity, even on the fourth range, is very good.

The note filter helps in obtaining selectivity to a very marked degree. We can take, as an example, the case of a signal arriving on a high frequency amplifier and note filter, where the resonance curves of the high frequency stage and the note filter are as shown below (Fig. 5). Now if we assume that we are receiving a station

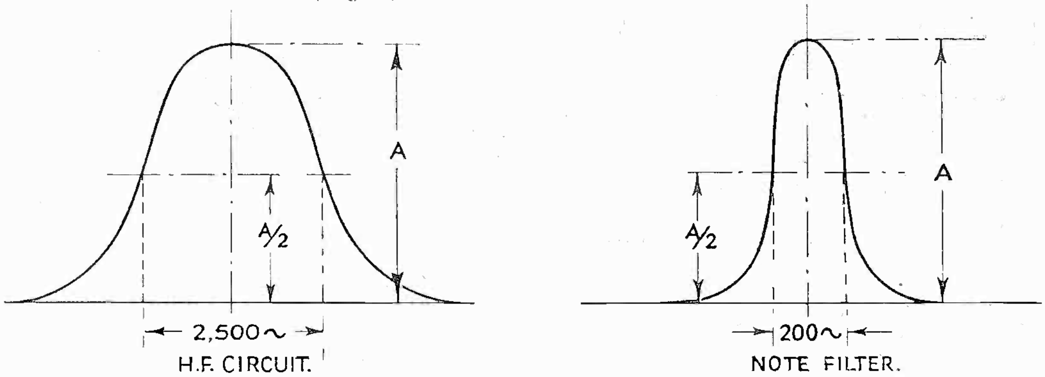


FIG. 5.

on, say, 13,600 λ or 22,000 ∿, and that another station is transmitting on, say, 14,100 λ or 21,200 ∿. Let us call these stations A and B respectively. The difference of frequency between A and B is 800 ∿. Hence, if the maximum ordinate of the resonance curve be made to coincide with the frequency of A, we shall obtain a strength of B approximately 3/4 that of A. Hence, the selectivity of the high frequency stage does not allow these two stations to be separated satisfactorily.

In two stages of H.F. magnification we shall obtain

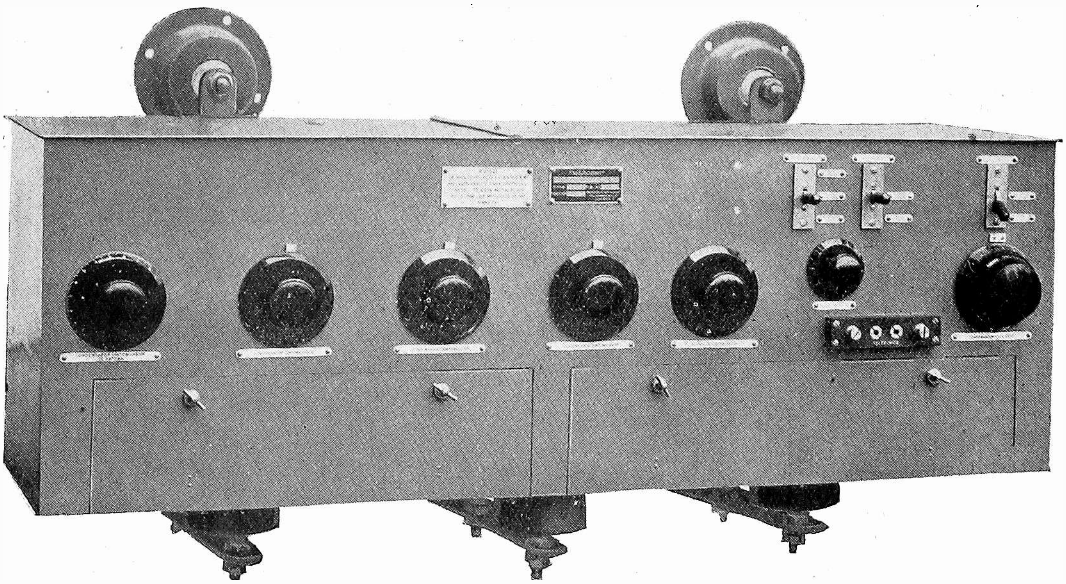
$$I_A : I_B :: 1 : 9/16$$

where I_A = intensity of Station A

I_B = ,, ,, ,, B

or, in other words, station B will be received at a little over half the strength of station A.

Now let us consider what happens in the note filter. Let us assume that the local oscillator is set to 23,200 ∿ to beat with A at 1,200 ∿. It will beat with B, therefore, at 2,000 ∿. But at 2,000 ∿ the resonance curve of the note filter has dropped to almost zero. Hence the intensity of A is now enormously greater than the intensity of B, and the two stations are adequately separated.



Marconi Receiver Type R.g.18.

In the case of the R.g.18 series, two models are at present made. These are

R.g.18 300—700 λ in one range
R.g.18a 150—800 λ in two ranges.

The tuner and amplifier for these instruments are contained in one box, and consist of the following components :—

Aerial tuning circuits.
2 stages of H.F. magnification.
Anode bend detector.
1 L.F. stage.
Local oscillator.

H.F. amplification is carried out by means of screened-grid valves which are transformer coupled. The transformers have a tuned grid winding and a tightly coupled anode winding. Greater selectivity is obtained in this way, and higher magnification. Such a circuit is practically immune from grid blocking.

As has been mentioned above this means of coupling cannot be resorted to in the case of the R.g.19 on account of switching arrangements.

MARCONI NEWS AND NOTES

Start Point Beacon Station

Start Point Lighthouse, with Wireless Beacon Station.

THE above illustration is of the Start Point Lighthouse in Devonshire, England, showing the wireless aerials erected by the Marconi Company for use with the Marconi Wireless Beacon Transmitter which has been installed at this station for the Corporation of Trinity House.

The Beacon Station Transmitter, which is installed in the building at the right of the photograph, is a standard pattern Marconi Beacon Station with a power of 500 watts and operated on a wavelength of 1,000 metres, which is the specified wavelength for wireless beacon stations.

Marconi Beacon Stations are entirely automatic in operation. No skilled staff is required, the routine work in connection with the transmitter being easily carried out by the ordinary personnel of the lighthouse.

Each Beacon transmitter has a distinctive identification signal—in the case of Start Point, G.S.M.—which enables it to be identified easily by unskilled listeners. This characteristic signal is normally transmitted twice in each hour, but in foggy weather it is transmitted more frequently for the duration of the fog.

The function of the Beacon Station and its characteristic signal is to enable ships fitted with direction finders to take their bearings from the known point at which the beacon station is situated and thereby to find their true course when approaching the coast.

The Marconi Company has taken a leading part in developing Wireless Beacon

Stations of the most reliable design. They have already installed stations of this type round the British coasts at

Round Island,
Skerries,
Spurn Lightship,
The Casquets (Channel Islands),
Start Point,
Bar Lightship,
Albatross (Coningbeg, Ireland),

and in the near future further beacon stations of the Marconi type will be installed at

Sule Skerry (Scotland),
Lundy North,
Dungeness,
Kinnaird Head (Scotland),
Cromer,
South Bishop,

and other places, in addition to similar stations for which orders have been received in other parts of the world.

Advantages of Marconi Beacon Stations.

One of the great advantages of the system of position finding in which a Wireless Beacon Station of the Marconi type at a known position is used in conjunction with a Direction Finder on board ship is that the signals are broadcast in all directions and a direct bearing can therefore be taken on the transmitter from any direction at every signal sent out by it. This method is, therefore, particularly suitable for lightship installation, as the swinging of the ship's head does not affect the accuracy of the bearing obtained, and navigators can lay off their wireless bearings on familiar points on the chart. This is an advantage possessed over rotating frame beacons, which are directive, and in consequence require the transmitting station to be fixed in position so that a stationary line of reference for the rotating frame is provided.

One of the many reports showing the reliability of the Marconi Beacon Stations comes from the Humber Conservancy Board. In November, 1927, a Marconi Beacon station was supplied to this authority for use on the Spurn lightship. For a full twelve months this set performed its functions day by day without the slightest fault, and the Chief Engineer to the Board recently wrote to the Marconi Company stating that as the Spurn lightship was coming in from her station for repairs this would be a good opportunity to inspect the Beacon station. This was done and the installation was found to be in excellent order. Considering that it had not even been visited by an expert during the whole time it had been at sea this shows that these stations can be relied upon to carry out their work under the most exacting conditions.

Another instance is that of the Beacon transmitter on the Mersey Bar Lightship at the entrance to one of the world's largest and busiest ports, which the Authorities report to have worked excellently and never to have closed down involuntarily throughout the whole of the twelve months of its operation.