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WIRELESS DIRECTION FINDING SYSTEMS FOR MARINE NAVIGATION

The importance of direction finders in marine navigation has long been recognised by companies exploiting marine wireless gear, who have developed their marine direction finders in the past few years to a very high degree of efficiency.

The general schemes of direction finding at present used in marine practice fall into two distinct groups:—

(1) *The Marconi-Bellini-Tosi system exploited by the Marconi organisation, who are the holders of the Bellini-Tosi patents.*

(2) *The rotating frame method exploited by S.F.R. in France, Telefunken in Germany, and R.C.A. in America.*

The above classification does not include the Robinson Rotating Frame System, which was originally designed for aircraft working, and which has been used at sea for some years.

The object of the following article is to give some idea of the relative merits of the two systems as regards marine practice.

THE past few years have conclusively proved what an extremely valuable navigational aid a marine direction finding receiver can be. There are numerous examples of wireless direction finders having been the means of saving life at sea, a fact which has been so far recognised that the Safety of Life at Sea Convention has demanded all passenger ships of 5,000 tons and above to be fitted with direction finders.

Although the importance of direction finders as an aid to navigation is now appreciated to the full, it is a regrettable fact that there is widespread ignorance of the fundamental principles and hence of the comparative merits of their various applications; it is the purpose of this article briefly to explain and compare the two systems in general use, namely the Marconi-Bellini-Tosi system and the rotating frame aerial system marketed by various other companies interested in marine communication.

None of the many possible variations of these systems has been adopted to a sufficiently large extent to merit consideration ; nor need we confuse the subject by discussing the different systems of directional transmission. In passing, however it is perhaps worthy of mention that the purpose of the ever-growing number of wireless beacons is merely to ensure the provision of wireless signals from known points of reference, that is to say, they are not themselves directional transmitters, they emit no beam and they exist solely for the benefit of ships upon which direction finding receivers are installed.

Appreciating the potential importance of direction finding in marine navigation, and having in mind the fact that the highest possible degree of accuracy was essential if the system were to become that indispensable safeguard it has, the Marconi Company were very early occupied in designing apparatus suitable for marine use. Holders of the Bellini-Tosi patents, the Company had already demonstrated in other fields the unquestionable superiority of the Marconi-Bellini-Tosi system, and it was obvious that there could be no decision but to incorporate Bellini-Tosi principles in the design of their marine apparatus. The pre-eminence of this system has been continuously maintained, throughout the rapid developments of recent years.

Basic Principles.

The basic principle upon which all systems of directional reception depend is that an aerial consisting of a simple loop of wire has receptive properties at a maximum in the plane containing the loop and at a minimum, or in the ideal case, zero, at right angles to this plane. Little consideration is necessary to realise that by connecting a suitable wireless receiver to such a loop, the latter being rotatable and fitted with compass scale and pointer, a very simple form of direction finder is obtained. Rotation of the loop through one complete revolution will produce two positions of maximum and two of minimum strength of signals from any continuously transmitting station to which the receiver is tuned. It will be found that, unlike the maxima, the minima are extremely sharply defined ; for this reason, observation of minima is the generally accepted method of reading wireless bearings.

A simple direction finder of the type described has the failing of 180° ambiguity ; that is to say, during one revolution of the loop two positions of minimum strength will be observed on any one transmitting station. These two positions should obviously be 180° apart and of course, only one indicates the correct bearing of the transmitting station.

Obviously such ambiguity could have very serious consequences in certain circumstances, but fortunately it is possible to embody a device for the purpose of indicating or "sensing" the correct bearing of the two observed.

General Marine Considerations.

All direction finders are subject to certain factors which are liable to influence the receptive properties of directive aerials and hence the accuracy of observations. It will be sufficient to state here that in the case of marine systems a quadrantal error as great as 12° may be obtained due to the effect of the metal hull of a vessel and that overhead wires, rigging, derricks and the like may produce appreciable errors in bearings.

Naturally, signals received by any source other than the D.F. aerial system will cause inaccurate observation, and it is therefore necessary to screen carefully all wires, coils, and other parts of the associated apparatus.

Another point of some importance is that when taking a bearing not only is it necessary to observe the relation of the pointer to the scale around which it moves, but to note at the same instant the "head of the ship." In other words, bearings are observed with reference to the fore and aft line of the vessel, for which due allowance must be made. In anything but a very calm sea it is naturally difficult to keep the ship's head steady to within one or two degrees and the importance of rapid and easy manipulation of the direction finder will be appreciated.

Description of the Systems.

The systems in general marine use at the present time fall into the two following groups :—

(1) The Marconi-Bellini-Tosi system exploited by the Marconi organisation.

(2) The rotating frame system exploited by numerous companies.

In the rotating frame system, there is a single frame which must be installed in such a position on the ship that manipulation of the loop can be effected either directly or by means of some mechanism from a position near the receiver.

The modern Marconi-Bellini-Tosi system consists of two loops of approximately the size of the rotating loop. These are arranged, one within the other, at right angles to one another, and they are fixed in the fore and aft line and athwartships respectively. Once fixed they do not rotate, their directional effects being reproduced on a small rotating coil within a component of the receiving apparatus, known as the radiogoniometer.

With either system a bearing is obtained by rotation of the appropriate mechanism until the position of minimum reception is observed by means of a pointer and scale, the latter being calibrated in compass degrees. The ease of manipulation of a small coil as compared with a loop aerial, however, gives the Marconi-Bellini-Tosi system a very definite advantage. The coil can be operated between finger and thumb, and, owing to the frames being fixed, rotation is absolutely independent of exterior wind pressure. In the alternative system, however, it is essential to rotate the frame through 360° which is not always an easy matter, particularly in heavy weather.

To facilitate ease of manipulation, a rotating frame requires periodical attention to ball-races, whereas the Marconi-Bellini-Tosi system offers complete freedom from aerial maintenance and cost.

Modern marine directional aerial systems of either type are robust and weather-proof.

Connections between Aerial System and Receiver.

It will be obvious that a rotating frame introduces complicated problems in the matter of connections to the receiver. A solution, upon which some manufacturers rely, is that of slip rings and brushes after the manner of electrical alternators, but brush gear nearly always produces parasitic noises particularly when dealing with weak, high frequency currents. It may be said that the adoption of brush gear tends to reduce the effective range of the apparatus.

Other manufacturers prefer to make permanent connections which limit the rotation of the frame. In this case the noise problem is avoided, but it becomes necessary to make special provision for sudden stopping of rotation in one direction and allow for rotation in the reverse direction.

Neither of these problems arises in the Marconi-Bellini-Tosi design.

Screening of Connecting Leads.

It has already been mentioned that reception of signals from any source but the aerial systems must be avoided, and it will be realised that special precautions are necessary to prevent the leads from the frames acting as aerials. Special care must also be taken to ensure freedom from induction from electrical machinery.

Here again the Marconi-Bellini-Tosi system has the advantage; with this system special low capacity screened cable is used and the efficiency of the apparatus is not impaired.

The rotating frame system, however, is tuned, that is to say, the loop also acts as a tuning coil, which precludes the use of the simple lead-covered cable. The greater the distance between frame and receiver, the greater the danger of vertical errors and of electrical induction, or, alternatively, the greater the expense in eliminating these dangers.

Frame Site.

In all systems, to obtain maximum efficiency the aerial systems should be placed :—

(1) In a position as far as possible from local ship's structures, for reasons stated earlier.

(2) As near the centre line of the ship as possible.

To fulfil condition (1) the usual site chosen is the bridge. This may not be convenient on ships carrying only one operator where the fitting must be such that operation can be performed from the wireless cabin. Fitting near the wireless telegraphy cabin may be impossible owing to ship's structures. In the Marconi-Bellini-Tosi system the frames may be placed at any distance up to 100 feet from the receiver, which fact permits a wide choice of frame site.

The rotating frame system has very limited flexibility in this respect. Driving the frame at a distance of 100 feet would generally be impossible and even if possible, the elaborate mechanism necessary would be very costly, as also would be the screening of the cables between frame and receiver. Again, it is doubtful if any mechanism would be sufficiently accurate over distances greater than 20 feet.

On some ships it is quite impossible to instal rotating frame apparatus satisfactorily.

Calibration.

In every case it is essential, after installation of a direction finder on a ship, to calibrate the deviation of incoming waves due to the ship's structure. Provided the apparatus has been correctly installed, the calibration usually consists of taking a number of wireless bearings and checking them against corresponding visual observations. The necessary corrections for different observed bearings may then be recorded for future use. The corrector may take the form of a table or curve of corresponding observed and true bearings to which reference may be made, or a distorted scale or other device for direct reading of the corrected observation.

In the Marconi-Bellini-Tosi, a simple adjustment is made within the instrument and no corrections are necessary thenceforward, the readings observed being "true." Some rotating frame systems incorporate a mechanical corrector on the hand-wheel.

Owing to the fact that the Marconi-Bellini-Tosi frames maintain a constant relationship to the ship's structures, the system has enormous advantages over the rotating frame system, which varies its relationship for each direction of incoming signal. It is this constant relationship which permits the use of the simple correcting adjustment referred to; for instance, the greater receptive properties of the system in the fore and aft line of the vessel would lead to a cramping of bearings towards that line but for the fact that the fore and aft frame aerial is proportionately smaller than its partner. This course is obviously impossible with the single rotating frame.

Comparatively few observations are necessary to calibrate the fixed frame system in the general case, the work occupying about five minutes. The usual practice when calibrating the rotating frame system is to swing the ship through 360° and to observe some 30 or 40 bearings before constructing a curve. This procedure in all cases occupies at least 45 to 60 minutes and entails considerable expense to the shipowners.

Operation.

There are two methods of taking D.F. bearings, namely " Swing " and " Point " methods. The Swing method consists of matching readings of equal strength on either side of the minimum and taking the mean reading. The arc of swing with the Marconi-Bellini-Tosi system is only about 5° on a normal shore station at 80 miles distance. Improvements in receiver design have made this possible ; a few years ago a swing of 20° to 40° was more usual.

Point bearings, which are a feature of a number of rotating frame systems, are obtained by means of a special exterior vertical aerial and an additional manipulating knob enables the operator to reduce the " arc of swing." Under ideal working conditions the arc would be approximately 3° at the same distance from the shore station.

In actual practice, however, owing to interference, conditions are rarely ideal, and it is seldom that shore stations send for long enough to permit manipulation of the compensating knob. Consequently, under normal marine conditions, the refinement of point bearings is not so valuable as would at first sight appear ; in fact, although it is used when taking observations on continuous wave signals, it is rarely used on Spark or I.C.W. transmissions.

Experienced operators have strongly condemned the point bearing feature as unsound, taking this standpoint from the following considerations :—

(1) Swing bearings may be taken much more rapidly.
(2) Less adjustment and manipulation necessary for swing bearings.
(3) The swing bearing method permits direct reading of the bearing in the Marconi-Bellini-Tosi system without the necessity of making quadrantal error corrections. (This applies equally to the rotating frame systems if a mechanical correcting attachment is provided).
(4) The point bearing of say 3° arc is of little more value than the swing bearing of say 5° arc obtained under similar conditions.

The " Sense " Device.

It is neither necessary nor desirable to dwell upon the theoretical principles of the device previously referred to herein for the purpose of surmounting the difficulty of 180° ambiguity. Suffice it to say that by arranging for signals to be received at one and the same time from both the frame system and a non-directional aerial, provided that certain precautions are observed, an indication as to which of the two minima is correct may be obtained.

It will occur to the reader that the constant use of this device would permit correct readings in the first instance in a single operation. Unfortunately, however, appreciable errors are liable to be experienced if that course were adopted and steps are necessary to discourage any attempt to read " sensed " bearings directly.

The "sensing" operation proves to be seldom necessary in practice, owing to the fact that the direction of a transmitting station, unless on another vessel, is generally known to within limits. Obviously, resort need only be had to the "sense" device, when doubt exists as to which bearing of two, 180° apart, is correct.

Only the following two operations are necessary to "sense" a bearing in the Marconi-Bellini-Tosi system :—

(1) Move a small Key Switch from "Bearing" to "Sense" position.

(2) Rotate the search coil, with which a minimum has already been found and to observe whether this minimum exists in relation to the "sense" pointer ; if not, it will be found that the opposite minimum does, but that may be assumed if desired without examination.

The total operation is extremely simple and occupies but a few seconds.

A very complex procedure is necessary to "sense" rotating frame bearings in the systems developed for Mercantile Marine use. Having taken a bearing by rotating the frame, in the normal manner, the following operations are required :—

(1) Put coupling pointer off zero position.

(2) Switch tuning switch to the appropriate waverange.

(3) Tune the vertical aerial to the incoming wavelength.

(4) Move coupling pointer to zero and further adjust the point.

(5) Rotate the frame through 90°.

(6) Move coupling pointer to find the minimum position and observe the reading on the coloured pointer on the handwheel coinciding with colour on the coupling pointer.

It will be agreed that there is no comparison between the two systems in the matter of simplicity of operation of the "sense" device. In fact, this is conceded to the extent that certain rotating frame systems developed for other than Mercantile Marine use, are being simplified, the modification following the Marconi-Bellini-Tosi lines.

Vertical Aerials.

That a "vertical" aerial, for non-directional reception, is an essential addition to a marine direction finding installation, will now be apparent. An exception would imply omission of the "sense" feature.

Modern Marconi-Bellini-Tosi installations do not require a separate aerial, the metal screening of the frame acting in its stead.

The saving in expense, the avoidance of unnecessary deck cutting and the elimination of unsightly additions to the aerial array are a few of the advantages claimed for this innovation.

Electrical Induction.

Successful operation of directional receiving apparatus on shipboard depends to a very great extent upon the amount of interference experienced from the ships' electrical machinery. Sparking of commutators of running machinery, the operation of switches, varying contacts in apparatus of all descriptions, all add their quota to the background of noise above which the operator must hear his signals. With any direction finder the operation requires the location of a reading of little or no signal strength but in searching for this reading the operator has to face a constant noise level.

The problem yearly becomes more formidable, owing to the increasing use of electrical machinery in marine practice.

Actual experience shows in this respect also the undoubted superiority of the Marconi-Bellini-Tosi system and in fact, cases have occurred in which the rotating loop system has been an impossible proposition, its rejection in favour of the Marconi-Bellini-Tosi system having resulted in thorough satisfaction.

The latter system owes its superiority to the following :—

(1) Cheap, simple, yet efficient screening. (The relative difficulties in screening adequately the leads from frame to receiver have been discussed earlier in this article).

(2) Flexibility of frame site, which permits the installation of the frame at the most induction-free position within 100 feet of the receiver, provided of course that due regard is paid to the two requirements previously mentioned.

Receiving Apparatus.

Although the necessary amplifying, tuning and detecting apparatus is not strictly concerned with the function of direction finding and, within limits, any suitable receiver could be used with either aerial system, it is extremely important that any amplifier designed to work in conjunction with a direction finding system should not affect in any way, the operation of the aerial system. It is the policy therefore, of the better-known wireless companies to design the associated receiving apparatus according to their own discretion and to satisfy a standard of selectivity and amplification which should meet most requirements. Unquestionably they should continue to market complete installations rather than to leave the onus of choice with the user. Not the least important advantage of this policy is standardisation and consequent economy.

In these circumstances, a brief comparison of receiving apparatus would appear to be justified. Receiving apparatus included in the majority of marine direction finding equipments falls generally within one of three classes, under the following headings :—

(1) "Screened Grid" Receivers.

(2) " Straight " Receivers.

(3) Superheterodyne Receivers.

The first class represents the very latest development in modern valve design. Valves of the screened grid type, when used in properly designed receivers, are so far superior to valves of the conventional type that the comparative merits of receivers can no longer be judged by the number of valves used.

For various reasons, an appreciable amount of high frequency amplification is necessary in a marine direction finder and the first mentioned class of receiver, as standardised with the modern Marconi-Bellini-Tosi system, comprises two screened grid stages, amply meeting requirements of amplification and selectivity. A detector and a low frequency amplifying stage follow.

Rotating frame systems generally employ receivers of the second or third classes. Dealing with the second class, *i.e.*, the " straight " receivers, these frequently comprise as many as four high frequency stages and three low frequency stages, in addition to the usual detector. The high frequency stages, however, do not employ screened grid valves, the circuits are complex, manipulation difficult and faults are by no means easy to locate.

Superheterodyne receivers while possessing the advantage of simple manipulation —simpler even than those of the screened grid class—have the following serious drawbacks :—

(A) They are extremely sensitive to interference from the ship's electrical machinery. (In some cases their rejection on this score has been essential. On a certain ship, for instance, in order to get results it was necessary to replace the rotating loop-superheterodyne combination with Marconi-Bellini-Tosi fixed frames and special receivers).

(B) They are peculiarly susceptible to interference from unwanted stations, even though the receiver may be tuned to a wavelength remote from that of the interfering stations. (Tests made over one year by one shipping company resulted in superheterodyne and rotating frame equipment being replaced by Marconi-Bellini-Tosi frames with special apparatus).

Waverange.

The waverange over which a direction finder is capable of working does not depend upon the type of frame system employed, but, as in the case of receivers various manufacturers have standardised their instruments in this respect and the subject is therefore entitled to mention.

In the latest Marconi-Bellini-Tosi marine system the very wide range of 180 to 1,600 metres is covered. This feature renders the apparatus equally valuable for use on trawlers where the 220 metres wavelength is used. Further advantages are that the direction finder can be utilised for the reception of gale warnings, weather reports and other matter transmitted on various wavelengths by broadcast stations, and for the purpose of taking bearings on these stations. Transmitting as they do throughout many hours of the day and night they may well be regarded as additional wireless beacons.

Whilst emphasizing the fact that there is no fundamental reason why other systems should not offer equal facilities, it is believed that as regards the Mercantile Marine the Marconi-Bellini-Tosi system alone covers a wider range than 450 to 1,200 metres.

Summary.

Heading.	Marconi-Bellini-Tosi System.	Rotating Loop Systems.
Frame Design	Two fixed metal shrouded loops approximately 2 ft. 6 in. diameter at right angles to one another (a smaller unit is available where space is confined).	One metal shrouded loop about 2 ft. 6 in. diameter capable of rotation on ball bearings.
Mechanics...	Rotation of small goniometer search coil by finger and thumb. No wind pressure to contend with. Ideal for Marine work. No brush gear troubles. No contact troubles, eliminating all electrical noise due to varying contacts.	Rotation of whole frame irrespective of wind pressure. Brush gear trouble and maintenance if frame is continuously rotatable. Mechanics much more complex.
Screening	Complete, efficient and inexpensive.	Screened cables cannot be used and effective screening is not only difficult but expensive and becomes more so as distance between frame and receiver increase.
Site of Frame	Clear field required. Centre line of ship required if possible.	Clear field required. Centre line of ship required if possible.
Flexibility	Frame can be fixed at any distance up to 100 ft. from receiver without any complex mechanism or costly screening of leads between transmitter and receiver.	Frame must be driven, and if far from receiver this means a costly fitting of frame drive mechanism and elaborate and expensive screening of leads from frame to receiver.
Receivers	4-valve, including S.G. H.F. stages, offering maximum selectivity, amplification and manipulative ease with minimum of trouble, maintenance cost and interference from local electrical disturbances.	(A) Straight circuits have eight valves which increase maintenance costs, render manipulation difficult, and necessitate a large number of controls. (B) Super heterodyne receivers possess very simple controls but suffer from drawbacks of interference and ships' noises, also harmonics from outside stations.

HEADING.	MARCONI-BELLINI-TOSI SYSTEM.	ROTATING LOOP SYSTEMS.
Wave Range	Wave range on marine design 180—1,600 m. This allows D.F. to be used on trawlers working on 220 m. and on broadcast stations for weather reports and as beacons.	Both (A) and (B) above 450—1,200 m.
Calibration	In the general case visual and D.F. checks on 45° points very quickly and cheaply carried out. Five minutes usually sufficient time required. Calibration choke set and bearings read quickly. Re-calibration can be done easily and quickly. The Marconi-Bellini-Tosi system once installed remains a constant relative to ship structures irrespective of direction of incoming signal.	In all cases a complete Q.E. curve must be taken and this takes at least 45—60 minutes. All bearings must be corrected by Q.E. curve and a mechanical corrector must be fitted and adjusted. Re-calibration means a repetition of the above process and is laborious. The rotating frame system varies its coupling relative to ships' structures for each direction of incoming signal.
Taking of Bearings ...	Swing bearings over narrow arcs (0°—10°). This is found quickest under Marine conditions. On spark and I.C.W. swing bearings almost as good as point bearings on rotating frame system.	Point bearings (0°—2°) on C.W. These involve (A) additional adjustment; (B) more time to take bearing. On spark and I.C.W. the additional adjustment for point bearings does not greatly reduce arc of swing against that on Marconi-Bellini-Tosi system.
"Sense" or True Bearing	Extremely simple and no possibility of making error.	Extremely complex and slow in the Mercantile Marine design and quite a good chance of making errors unless well versed in manipulation of set.
Vertical Aerials	(1) Not necessary for taking bearings. (2) Necessary for "sense" bearings. Incorporated in frame design and do not require expense of separate vertical aerial fitting.	Necessary for both point and "sense" bearings. Not incorporated in frame design necessitating additional expense of a separate vertical aerial.
Induction	Not very sensitive to induction owing to— (A) Flexibility allowing frame to be placed in induction free positions. (B) Perfect and cheap screening between frame and receiver.	Very sensitive to induction owing to— (A) Non-flexibility of fitting. (B) Difficulty of perfect screening between frame and receiver.

RADIO TELEPHONY DISTORTION

A particular type of distortion occurring in Short Wave telephony and telegraphy reception, involving a partial disappearance of modulation with retention of carrier signal has been noticed on many short wave stations, especially when the receiver is within the skip distance of the transmitter.

An attempt to explain this phenomenon is given in the following article.

Some correspondence bearing on this subject was published in our last issue.

MOST of the causes of distortion in radio Telephony have been discussed from time to time, under the headings of "frequency distortion" "selective fading of the side bands and carrier," etc., but there is one effect which has not received the attention it deserves, and which it is proposed to discuss in the following article.

It has been noticed that in certain conditions, the carrier of a telephone station is strongly received but with very little or no trace of modulation.

This has led, in certain cases to accusations of insufficient modulation from the receiving end, which have been indignantly repudiated by the sender. Such a state of affairs may well be ignored by the casual observer who does not know what exact amount of modulation to expect, but an experienced observer can detect the effect at once, and sufficient data has been collected to leave one assured that it is genuine. The effect is most marked within the skip distance. As an example, the Broadcast Station 5 S.W. at Chelmsford working on a wavelength of 25 metres received at Somerton gave a measured carrier so strong that in normal conditions strong modulation should have been heard, yet the modulation was inaudible except for faint sounds at rare intervals. A similar effect has been observed in telephone transmission from aeroplanes where, in the skip distances, strong carrier waves without modulation are often reported.

The following tentative explanation is offered :—If a single short impulse is sent out by a transmitter, oscillographic and facsimile reception methods show in general the existence of more than one impulse at the receiver. Sometimes as many as four to five separate echoes following at intervals of a millisecond or so are received, and in some cases where scattering is present, a single short impulse may be received as a prolonged signal spread over an interval of 20 milliseconds or so. The later echoes or scattered signals owe their delay to having travelled by a longer path, the various possible paths being represented diagrammatically in Fig. 1 as ricochets between the earth and the Heaviside layer. When scattering is present, the signals may follow irregular paths from scattering centres, distributed in the Heaviside layer as illustrated in Fig. 2, where BOR represents the paths of the scattered signal from a Beam Station at B, say, BR being the direct signal.

Whatever the mechanism may be that causes them, these echoes undoubtedly exist. Consider now what will happen if a train of dots of frequency 500, say, is sent out, and echoes of $\frac{1}{1{,}000}$ sec. delay are prevalent. The curve A (Fig. 3) will represent the first signal, the curve B in which the dots exactly fill up the spaces in A will represent the second signal. If the A and B signal are of equal intensity, the envelope of the sum of the two will be a straight line, and on reception and rectification, the received detector current (except perhaps for the momentary effects of change of phase at the junction of the A and B—dots) will be a constant current, and there will be no modulation although the carrier is strong. Although this illustration represents an extreme case, it requires but little consideration to see that in general where there are many echoes, the modulation will be reduced relatively to the carrier by the filling up of the spaces in the transmission. An effect of almost exactly this nature has been observed when listening at Chelmsford to the local Beam stations which are so close as to be within the skip distance. In such cases it is very often observed that when listening to dots at high speed the signal is almost completely blurred into a nearly continuous dash.

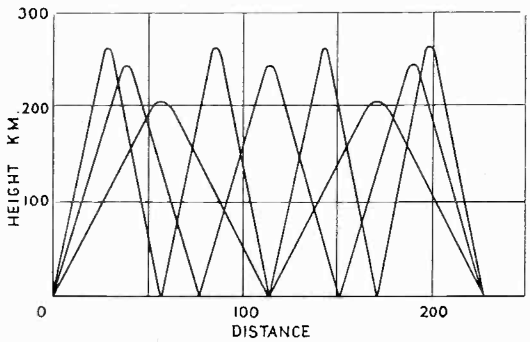

FIG. 1.

The effect is most marked in the skip distance because the relative intensity and delay of the echo signals are greatest in such conditions. It is perhaps not quite so easy to see what happens when the direct and echo signals do not fit in so exactly as specified above in the simple explanation. The attempt to analyse the effect by the consideration of the side bands appeared at first sight to contradict the foregoing reasoning. Thus in a scattered field, for instance, where this effect is most marked, the electromagnetic forces are made up of the sum of a number of more or less equal contributions of random phase. In accordance with Rayleigh's Theorem the energies of each component have to be added, not the amplitudes, and the final amplitude is the square root of the sum of the squares of the contributing amplitudes, *i.e.*,

$$\bar{E} = \sqrt{E_1^2 + E_2^2 + E_3^2 + \ldots \text{ etc.}}$$

In the same way we take the energies of the side waves, add them and take the square root to obtain the resultant side wave amplitude, *i.e.*,

$$E^1 = \sqrt{E_1^{12} + E_2^{12} + \ldots}$$

Now since in transmission, except for accidental phase interferences,

$$\frac{\overline{E}^1_1}{E_1} = \frac{E^1_2}{E_2} \quad . \quad . \quad . \quad = K$$

the ratio of the transmitted side wave, to transmitted carrier, therefore $\frac{\overline{E}^1}{E} = K$ on the average.

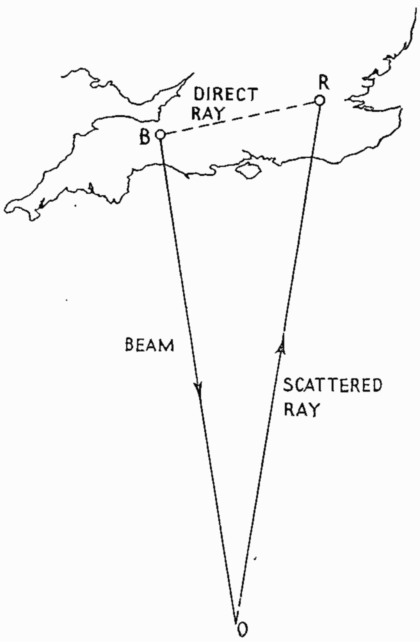

FIG. 2.

It would therefore appear that there is no average reduction of the side waves relative to the carrier ; *i.e.*, the processes of transmission, scattering, etc., alter the carrier and side waves equally leaving the ratio constant, and since the depth of modulation depends on this ratio, it, apparently, remains constant.

The contradiction is cleared up if we take account of the relative phase of the carrier and side bands.

Strictly speaking the phase of the side bands $2\pi\ (v_1 - v_2)\ t + \theta$, or $2\pi\ (v_1 + v_2)\ t + \theta_2$ of a simple sine modulated wave (where v_1 is the carrier frequency and v_2 is the modulation frequency) does not differ from the phase of the carrier $2\pi v_1 t$ by a constant amount but varies through a whole cycle of $360°$ in a period of the modulation.

But if we combine the two side waves

$$\left.\begin{aligned} &\frac{K_1}{2} \sin \left\{2\pi(v_1 + v_2)t + \theta_1\right\} + \frac{K_1}{2} \sin \left\{2\pi(v_1 - v_2)t + \theta_2\right\} \\ &= \quad K_1 \sin \left\{2\pi v_1 t + \frac{\theta_1 + \theta_2}{2}\right\} \cos \left\{2\pi v_2 t + \frac{\theta_1 - \theta_2}{2}\right\} \end{aligned}\right\} \quad . \quad . \quad (1)$$

and compare this with the carrier wave sin $(2\pi v_1 t)$, say, the high frequency component of (1) $\sin\left\{2\pi v_1 t + \frac{\theta_1 + \theta_2}{2}\right\}$ has a definite phase relation or phase difference $\frac{\theta_1 + \theta_2}{2}$ from the carrier wave. When we spoke of the phase difference between carrier and side waves we implied this quantity. In a scattered field we have assumed that this phase is a random quantity.

This is justified if we consider the mechanism of scattering ; the phase on any path is $\int \frac{ds}{v}$ and this varies for the different paths and different frequencies, and since the paths are randomly distributed, the individual and resultant phases will also be randomly distributed.

Again, according to (1) the phase of the modulated envelope is $\frac{\theta_1 - \theta_2}{2}$, and, therefore, $\frac{\theta_1 - \theta_2}{2}$ will represent the delay times of one of the modulated signals, which we have seen from observation vary at random in a scattered field up to

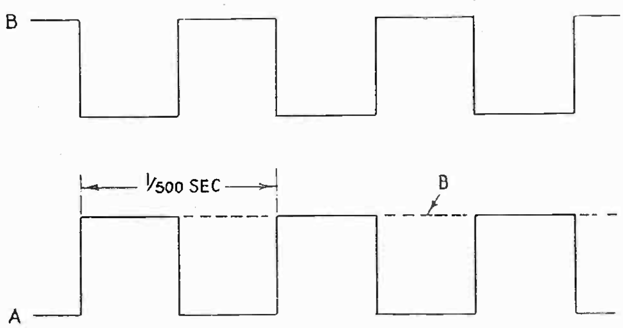

FIG. 3.

20 milliseconds or more. We must therefore, as a matter of observation, consider $\frac{\theta_1 - \theta_2}{2}$, and therefore θ_1, θ_2, and $\theta_1 + \theta_2$ a random quantity. The resultant of side bands and carrier for one modulation frequency v_2 will be

$$Z = \sin 2\pi v_1 t + K_1 \sin\left(2\pi v_1 t + \frac{\theta_1 + \theta_2}{2}\right) \cos\left(2\pi v_2 t + \frac{\theta_1 - \theta_2}{2}\right)$$

Let $\qquad 2\pi v_1 t + \frac{\theta_1 - \theta_2}{2} = X$ say, and $\frac{\theta_1 + \theta_2}{2} = \theta$

Then we have $\qquad Z = \sin(2\pi v_1 t) + K_1 \sin(2\pi v_1 t + \theta) \cos X$

Expanding the latter term we get

$$\sin 2\pi v_1 t\,(1 + K_1 \cos\theta \cos X) + \cos 2\pi v_1 t\,(\sin\theta \cos X)$$

and the modulated amplitude is therefore

$$\sqrt{(1 + K_1 \cos\theta \cos X)^2 + K_1^2 \sin^2\theta \cos^2 X}$$

$$= \sqrt{1 + K_1^2 \cos^2 X + 2K_1 \cos\theta \cos X} \quad *$$

* Mr. Ladner has used a Vector method to show these results.

This gives a modulation envelope which, when $\theta = 0$ or $n\pi$, is of the usual form $(1 \pm K_1 \cos X)$, but which when $\theta = (n + \frac{1}{2})\pi$ is $\sqrt{1 + K_1^2 \cos^2 X}$.

In the form (1) the envelope lies between the limits $1 + K_1$, and $1 - K_1$, and in form II between 1 and $\sqrt{1 + K_1^2}$, which when K_1 is small represents a very small variation. The curves in the figure show the modulated envelopes in the cases for $K_1 = \frac{1}{2}$. They indicate that where the side waves are misphased 90° (in the above sense), the modulation is very largely reduced, and will be so for all values of θ not 0 or $n\pi$, *i.e.*, for all cases of misphasing from the normal. The resultant modulation to be expected where θ is a random quantity is always less than the normal modulation transmitted.

If all values of θ are equally probable we obtain an "average modulation" curve of the form

$$Y = \frac{1}{\pi}\int_0^\pi \sqrt{1 + K_1^2 \cos^2 X + 2 K_1 \cos X \cos \theta}\, d\theta$$

We will suppose K_1 is small, as it nearly always is for each particular modulation frequency

Then if $a = 1 + K_1^2 \cos^2 X = 1 + K_1^2 \cos^2\left(2\pi v_2 t + \frac{\theta_1 - \theta_2}{2}\right)$

$b = 2K_1 \cos X$

then $$Y = \frac{a^{\frac{1}{2}}}{\pi}\int_0^\pi \sqrt{1 + \frac{b}{a}\cos\theta}\, d\theta$$

where $$\frac{b}{a} = \frac{2K \cos X}{1 + K^2 \cos^2 X}$$

and is always <1, and small if K_1 is small.

We may expand the square root and obtain

$$Y = \frac{a^{\frac{1}{2}}}{\pi}\left\{\int_0^\pi d\theta + \int_0^\pi \frac{1}{2}\frac{b}{a}\cos\theta d\theta - \int_0^\pi \frac{1}{2}\cdot\frac{1}{2}\frac{1}{1.2}\frac{b^2}{a^2}\cos^2\theta d\theta + \text{etc.}\right.$$

and integrating

$$Y = a^{\frac{1}{2}}\left(1 - \frac{1}{16}\frac{b^2}{a^2} + \text{etc.}\right)$$

which to the first approximation is $a^{\frac{1}{2}}$, *i.e.*, the average modulation is

$$a^{\frac{1}{2}} = \sqrt{1 + K_1^2 \cos^2 (2\pi v_2 t + \theta^1)}$$

which is always small compared with the normal modulation.

Thus, for instance, if K_1 is 10 per cent., $a^{\frac{1}{2}}$ varies between 1 and $1 + \frac{1}{200}$ with an effective modulation of $\frac{1}{4}$ per cent., *i.e.*, a very great reduction of modulation.

It therefore would appear that in a scattered field, where the side waves may be random phased with respect to the carrier, the modulation is distorted (see Fig. 4) and very much reduced.

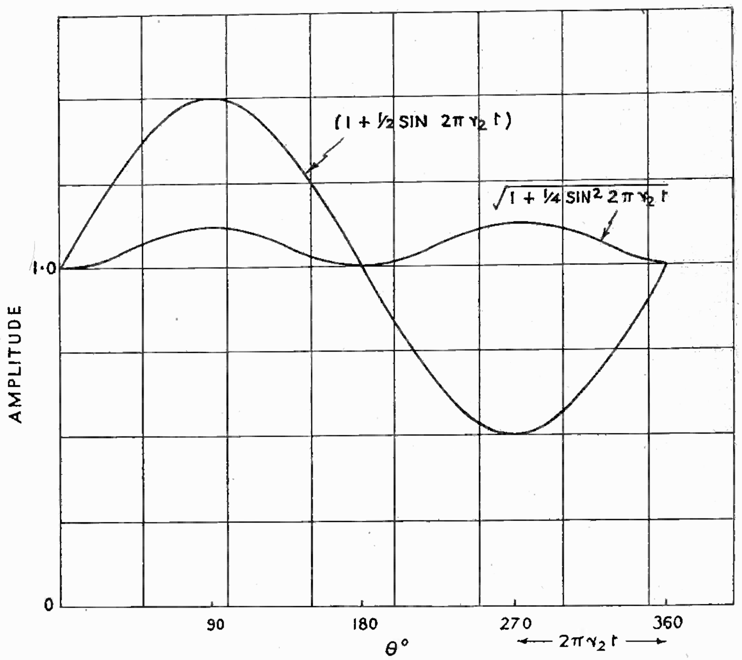

FIG. 4.

It might perhaps be thought that the side band method of treatment was unnecessary in view of the clear picture of the smoothing of the modulation given in the original description, but apart from the added satisfaction of explaining the effect by two methods, it brings to light a fact which is not obvious in the former explanation, viz., that single side band transmission with suppressed carrier will eliminate this effect.

It is clear that if a single side band only is transmitted then whatever its phase may be, it produces a fully modulated tone in beating with the carrier supplied at the receiving end.

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and integrating

$$Y = a^{\frac{1}{2}}\left(1 - \frac{1}{16}\frac{b^2}{a^2} + \text{etc.}\right)$$

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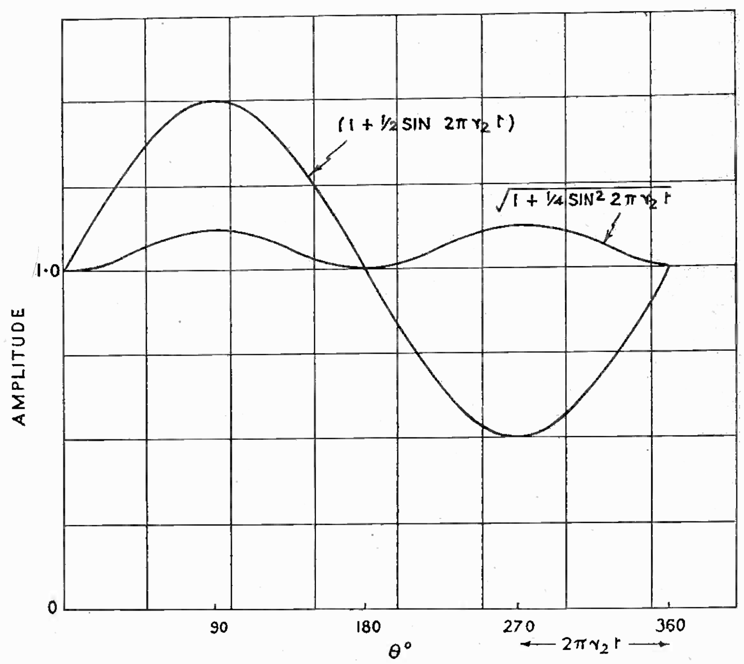

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It is clear that if a single side band only is transmitted then whatever its phase may be, it produces a fully modulated tone in beating with the carrier supplied at the receiving end.

Thus

$$\text{Side band} = K\,E \sin\left(2\pi\,(v_1 + v_2) + \theta\right)$$
$$\text{Heterodyne } E \sin\left(2\pi v_1 t\right)$$

which varies in amplitude from $\overline{E} + K\,E$ to $\overline{E} - K\,E$ according as the two are in phase or out of phase, *i.e.*, the modulating amplitude has a range 2KE, and is fully modulated.

Single side band suppressed carrier methods will have the advantage of eliminating this type of distortion and reduction of modulation. Such methods, though already attempted on short waves, have been attended with great difficulty, since the frequency separation of the side waves from the carrier is such a small percentage of the carrier frequency that any lack of stability of the latter will carry the frequencies outside the filter bands and fail to eliminate the carrier and one side band.

Improvements in frequency stability of transmitters will probably enable such methods to be used, and will not only eliminate the effect discussed, but also the more normal type of fading dependent on the product of the carrier and side band intensity.

T. L. ECKERSLEY.

LINE TRANSMISSION UNITS

The Technical Editor of THE MARCONI REVIEW *publishes below some correspondence relating to an article entitled "Notes on Transmission Measurements" which appeared in* THE MARCONI REVIEW, *No.* 24, *for September,* 1930.

Attention is directed to the last letter, in which Mr. C. E. Rickard weighs the relative pros and cons of the use of transmission units when discussing wireless circuits, and in particular to the table given therein, which should prove of especial interest to the wireless engineer as it provides a simple method of correlating transmission units and voltage or current ratio measurements.

"Sir,—The advocates of line transmission units are rapidly submerging the wireless engineer with their ideas of measurement and one is tempted to ask whether the line engineer's angle of view is sufficiently like that of the wireless engineer to make the former's system suitable for high frequency work.

The article in the September number of THE MARCONI REVIEW entitled 'Notes on Transmission Measurements,' sets out the telephone engineer's viewpoint to some extent and provides food for thought. For instance, the writer of the article remarks that 'it should be clearly understood that all units used for the measurement of transmission characteristics are relative.' This is a somewhat definite statement and conveys the fact that the relative measurements are of more importance in transmission work than the absolute measurement of power at any point. It may be clearly understood by the telephone engineer, but to the average wireless man the point is not at all obvious and on the face of it a relative measurement is not of particular interest in itself.

Two amplifiers may each have a gain of 50 DB, but this fact in itself conveys nothing. One amplifier might be contained inside a cigar box, and cost £1, whereas the other might require a building to house it and cost £10,000.

The truth is that the line engineer is involved to such an extent in closely inter-connected circuits whose levels are maintained at a fairly constant value, that it is relative values he talks in, but although he talks in these relative values, he has at the back of his mind all the time an input of definite value which is implied, if not actually stated.

Further his apparatus is always matched to a line of known constants both as regards input and output. In fact, it is the line which is the controlling factor in the system and it is because the terminations are always the same that a relative system becomes useful.

In high frequency work we have no lines to match, our input impedances are various (and in many cases difficult to measure), we have a great variety of output impedances, in very few cases do input and output match, and in consequence it becomes necessary to specify actual power output and input volts. Because of this, because the terminations are different and because of the necessity for stating actual figures, it makes the relative measurement of little interest, and it would be a great pity for us to adopt wholesale the telephone engineer's terminology, particularly as the units do not appear to be of too stable a character. For if the table given on page 19 is studied, it will be seen that the line engineer has had a good many attempts to find a suitable unit of relative loss (or gain) and it seems unfortunate that the most recent conference on the subject should still leave the matter ambiguous, that is, if the quotations given set out the findings of the C.C.I.

Once it is realised that the only true measure of loss (or gain) is one of power, then a unit dealing in relative loss (or gain) should be a power ratio. The voltage or current ratio is completely meaningless (unless qualified), besides which it leaves the use of the unit ' bel ' ambiguous, and the retention of such additional units having the same name appears to the writer to be a confession of loose thinking.

The ambiguity is carried still further by allowing the individual to fix his own zero level, instead of making a definite ruling on the matter and bringing all people into line. If it is agreed that zero level is a reference point, then for the sake of clearness one would expect that reference point to be fixed, even though that fixing is not wholly suitable to everyone's taste.

In some ways it would be logical to put frequency on a relative basis since the discrimination of tone is logarithmic, in fact, it has been suggested, but I cannot visualise the wireless man being so misguided as to fix zero level at any point that suited him, although to one section 10^7 would be a convenient zero level, and to another 10^4 ; the broadcast engineer would be torn between two desires, to have one level at about 10^6 and another at 10^3.

A further limitation to the present decibel assessment is that it can only be applied to a proper amplifier, that is, an amplifier which is working sinusoidally, but in high frequency transmission work many of our amplifiers are not working sinusoidally.

No doubt the bel will in due course find its own level in the scheme of things (and in its way it is of value), but at the moment being somewhat new, what might be called the percentage method of thought is in danger of being overdone and one finds the bel in peculiar places. Quite recently a foreign government called for tenders for telephone switchboard apparatus having sufficient switches such that the ratio of calls lost to what is known as ' busy hours ' was not greater than such and such a figure. One manufacturer in quoting expressed the ratio of calls lost to ' busy hours ' in decibels.

These observations are made, not in the spirit of criticism, but because of the close link that is developing between the line and wireless engineer it is essential for each to understand the other's language and a little expansion of the article in question would be of general interest to the wireless man.

Chelmsford College. A. W. LADNER.

December 3rd, 1930."

" Sir,—I beg to reply to the points raised by your contributor as follows :—

1. An objection is raised to the statement in THE MARCONI REVIEW that all units used for the measurement of transmission characteristics are relative, and this statement is taken to mean that relative measurements are of more importance than absolute measurements. The next paragraph in the Review, however, shows that an absolute measurement of power is obtainable in the system by making a measurement of level. The great advantage inherent to the use of a relative measurement lies in the fact that a ratio of input to output may be specified together with a maximum output level and this information completely defines the operational ability of the apparatus in question, except with regard to the matter of phase shift. In common with any other piece of electrical apparatus it is essential that its impedance be suitable for the circuit in which it is connected, for even motors, lamps, stoves, etc., have their impedance arranged to suit the existing conditions.

2. The critic states that ' two amplifiers each may have a gain of 50 DB, but

this fact in itself conveys nothing : one amplifier might be contained inside a cigar box and cost £1, whereas the other might require a building to house it, and cost £10,000.'

This is true ; it is essential also to state the maximum input or output level, and the frequency range over which it is designed to operate.

3. It is also true that the line engineer talks in relative terms, while implying a definite reference value.

Next, it is a fact that line apparatus is matched in a specific manner to a line of known constants both as regards input and output. Is not this so with every piece of electrical apparatus, where effective and efficient operation is desired ? It is, however, wrong to assume that it is because the terminations are always the same that a relative system becomes useful ; the terminations are, in fact, not always the same. The fact that the input and output impedances may be unequal does not preclude the possibility of measuring the loss or gain in the system of Line Transmission Units which are in general use.

4. It is stated that the decibel assessment of gain can only be applied to an oscillator operating with a sinusoidal input, whereas most transmission (presumably radio transmission) work amplifiers operate on the flick impulse system. But it would appear that a radio amplifier may be treated exactly like a telephone line amplifier. Such an amplifier is required to operate over a large range of frequencies and with peculiar and ever-changing waveform. The gain of an amplifier is measured at one or more frequencies within its operating range with a sinusoidal input, and provided the maximum amplitude of the potential applied to the input under working conditions is not sufficient to bring about distortion, the gain will remain substantially the same no matter what the waveform may be, so long as it contains no frequencies outside the specified range. If therefore, the maximum input or output level be stated as well as the gain or loss over a specified frequency range, the measurement becomes complete except for the phase shift.

5. The units employed in Line Transmission Measurement are not unstable as suggested by the critic. This table on page 19, together with the context, was drawn up in order to show the history of the development of the present Line Transmission Units, and to show how they are related to their predecessors. The present state of the units is really not ambiguous, for as stated on page 15, ' two new units, the Bel and the Néper were recommended as the basis of all future communications measurements.'

6. It is stated in the criticism that ' once it is realised that the only true measure of loss (or gain) is one of power, then a unit dealing in relative loss (or gain) should be a power ratio. The voltage or current ratio is completely meaningless (unless qualified), besides which it leaves the use of the unit " bel " ambiguous, and the retention of such additional units having the same name appears to the writer to be a confession of loose thinking.'

The first sentence is perfectly correct as is shown on page 17 of the article in question. The second sentence is also correct inasmuch as a statement of voltage or current ratio is useless unless the input and output impedances are the same. The second part of the latter sentence is incorrect since the use of the unit ' bel ' is not ambiguous and it is incorrect to state that ' the retention of such additional units, etc., is a confession of loose thinking,' because there are no additional units having the same name, although the decibel was originally known as the Transmission Unit, *i.e.*, two names for one unit, however, the Transmission Unit is now obsolete. Possibly the critic refers to the use of the $\frac{V_1}{V_2}$ and $\frac{I_1}{I_2}$ ratios as 'additional units with the same name.'

7. Although different people are in the habit of fixing their own zero level, it is believed that an official zero level of 1 milliwatt has been fixed for testing purposes.

8. The measurement of frequency in terms of a zero level although possible is not at all to be desired and the objections raised by the critic are entirely endorsed by the writer.

As is the case with most new things which have a popular appeal, the Line Transmission Units of Measurement may perhaps be applied to unsuitable cases by persons who are not familiar with their limitations, but it is considered that where a sympathetic study of the uses and applications of the system is made, a great advantage will be found to accrue in the matter of ease of calculation and simplicity of description of the operational characteristics of apparatus.

It is hoped that the foregoing remarks may help to elucidate the terms and the line of thought involved in the system under review.

Marconi House,
Strand, W.C. 2.
January 22nd, 1931." O. S. PUCKLE.

" Sir,—At first sight, I thought that the fulfilment of your request for me to round off the interesting discussion between two of your contributors on the subject of the transmission unit would be as simple a task as it is congenial. I find, however, on going more closely into the articles in the September and the present issue that the two authors have left little to be said.

In considering their different points of view I think that in order to get the right perspective we require to study the *raison d'être* of the transmission unit and the objective of the telephone engineer as compared with that of the radio engineer or any other scientist to which the 'decibel' might be of interest.

From the point of view of the transmission of electrical energy it might fairly be said that the telephone engineer is single-minded and that his great object in life is to maintain a certain level of energy, that is to say, his purpose is to transmit the equivalent energy of the human voice, whose level for normal conversational purposes is definite and moderately constant, over a landline and deliver it at the other end at the same intensity. A convenient level of intensity has been established arbitrarily as 1 milliwatt delivered into a 600-ohm terminal impedance, and is known as 'zero' level.

In the early years of telephone development the telephone engineer was not greatly concerned with transmission losses because his distances were then relatively small and he was concerned mainly with overhead lines, but so soon as development demanded transmission through cables, or over long landlines, the problem of losses in transmission became very evident. At the outset the workers in the telephone industry found it convenient to measure the losses in terms of the 'mile of standard cable,' and by means of exponential formulæ the losses on lines or cables could be reduced to a common basis. Three points of interest emerge from this, which differ from the ordinary engineer's standpoint, viz. :—

(A) that the telephone engineer deals with an average level of power of the order of one milliwatt ;

(B) his thoughts are concerned with losses rather than efficiencies ; and

(C) his efficiencies are 'exponential' whereas the power engineer's losses are additive.

Thus, if the loss of energy in a telephone transmission line one mile long is 10 per cent., the efficiency or ratio of output to input at the end of 4 miles of the line will be $\left(\frac{9}{10}\right)^4$ whereas, if the C^2R loss over a power line one mile long is any given amount, the loss over 4 miles of line will be four times that quantity.

So soon as the telephone engineer had at his disposal means of making good his losses by means of repeaters, he became concerned with relative gains, as well as relative losses. The relationship between the gain of the repeater and the loss on the line is clearly very intimate, the objective being to bring back the weakened speech signal to normal value, or to increase it to some extent above normal, so as to make up for further losses in the next section of line or cable.

But here came the difficulty ; whereas the telephone engineer could measure his losses in terms of miles of standard cable, it would have been incongruous to measure the gain of his repeater in the same units.

The natural development was therefore to adopt a unit, known as the transmission unit, which could be equally well applied to losses in cables, or gains in amplifiers. The need for such a unit was so obvious that the basic T.U. adopted by the Bell Company was accepted internationally under the name of 'decibel' or 'db' and to satisfy the purists who felt that the new unit should be based on the naperian logarithm, since basic calculations are made in terms of powers of ϵ, the alternative units of 'decineper' and 'neper' were also established.

The adoption of an 'exponential' unit has particular value in telephone engineering, not only because the line efficiencies are exponential in relation to their length, but also because the gains of amplifiers are exponential in relation to the number of stages used, the losses in filters are exponential in relation to the number of cells and, last but not least, the appreciation of relative acoustic energy by the human ear is exponential in character. Hence to calculate losses over a given number of miles of line or cable, or the gain of an amplifier, the telephone engineer has merely to subtract or add the indices, *i.e.*, to say logarithms of his exponential ratios, or in other words, to add or subtract the number of decibels loss or gain.

Thus it may be said that the so-called transmission unit, or exponential unit of ratio, filled a long-felt want.

Let us now make quite certain what is this unit. According to definition we have, when comparing relative input and output energies, or vice versa,

$$\text{Number of bels} = \log_{10} \frac{P_1}{P_2}$$

$$\text{Number of decibels} = 10 \log_{10} \frac{P_1}{P_2}$$

$$\text{So that 1 decibel} = \text{ratio } \frac{10^{\cdot 1}}{1}$$

$$\text{And 1 Bel} = \text{ratio } 10^1 = 10/1$$

Similarly when comparing amplitudes we have—

$$\text{Number of nepers} = \log_\epsilon \frac{V_1}{V_2} = \log_\epsilon \frac{I_1}{I_2}$$

$$\text{Number of decinepers} = 10 \log_\epsilon \frac{V_1}{V_2} = 10 \log_\epsilon \frac{I_1}{I_2}$$

$$\text{So that 1 decineper} = \text{ratio } \frac{\cdot 27183}{1}$$

$$\text{And 1 neper} = \text{ratio } 2{\cdot}7183/1.$$

Thus, when we say that an amplifier has a gain of say 20 decibels or 2 bels, we mean that the ratio of $\frac{\text{output}}{\text{input}} = 10^2 = 100$. Similarly, if we wish to compare amplitudes, such as the ratio of $\frac{\text{output signal strength}}{\text{input signal strength}}$ in an amplifier, we may define the gain as so many nepers.

It is obvious that with the foregoing we have a convenient recognised scale of definite ratios and as such there seems no reason why we should not make such use of it as may seem fit and proper.

But so soon as we begin to use it we immediately realise its limitations, and that a statement of gain or loss in decibels, *i.e.*, to say the use of a ratio, conveys an incomplete impression on the mind unless it be accompanied by a reference point or level. When an engineer makes a statement that an amplifier has a gain of 10 decibels, or a cable has a loss of 10 decibels, the information conveyed is simply a ratio, that of output to input. We cannot compare two amplifiers each having a gain of say 60 decibels unless we know either the input or the output, *i.e.*, to say some reference point ; we could not compare a receiving amplifier with a power amplifier. Still, all receiving amplifiers deal with a received signal of the order of microvolts, and their outputs are usually of the order of milliwatts, that is to say, they deal with feeble currents and powers where losses or gains of energy have no great financial consequence as regards loss or gain of power. For example, a telephone engineer can contemplate losing 99 per cent. of his available energy with equanimity, knowing that he can multiply what is left by 100 at little cost in fuel or power. But, should a radio engineer talk of a power amplifier having a gain of say 50 decibels, unless the output of the amplifier be given in kilowatts, the information would be of little value. Or take the case of short wave feeders, the receiving engineer can contemplate a loss of one decibel between aerial and receiver without turning a hair, but the engineer responsible for the transmitting station design cannot but be greatly concerned with such a loss in a transmitting aerial feeder. To the receiving expert the loss of one decibel is only just perceptible by the human ear, a matter of little or no importance, but to the transmitting expert one decibel may mean several kilowatts, which have to be provided and paid for. It follows, therefore, that the use of the 'decibel' and allied units is peculiarly adapted for the comparison of weak or negligible power values, which may vary exponentially, that is to say, in enormous proportions and yet at their maximum be measured in fractions of a watt. Particularly as regards telephony and acoustics, where the power involved is negligibly small, and varies as regards its manifestations in accordance with an exponential law, the decibel unit is a very valuable measure which conveys relative values to the human brain, in a more easily comprehensible way to the trained mind than the mere statement of a large numerical ratio. When the reference power exceeds a few watts, the question of the power involved becomes vital, and one cannot readily assimilate ratios of power except as 'efficiencies,' *i.e.*, to say percentages of output to input. In such cases the loss of even a small percentage is of importance—so that the measure of such losses by the transmission unit would be in small fractions of a decibel.

It follows that where we have to deal with large variations or ratios of comparatively small input and output power, such variations being exponential in character, the decibel gives us a very valuable means of conveying and assimilating information, especially when accompanied, as it must be, with a reference level or datum. On the other hand, the use of the decibel when dealing with large power inputs and outputs, fails to convey in an explicit manner a proper appreciation of the powers involved, and a statement of efficiency ratio is then better expressed in the normal way as a percentage.

For those engineers who are not in daily contact with the elusive decibel, the following tips may be found useful as a means of rapid assessment of the numerical ratio of a gain or loss expressed in decibels without reference to tables. It is only necessary to commit to memory two key values, viz., 10 decibels corresponds to the ratio 10/1 and one decibel corresponds very approximately to the ratio 5 to 4 or $1\frac{1}{4}$ to 1, or 1 to ·8. Starting from 10 db. downwards, we can at once write down the db. table of ratios thus :—

								True value.
10 decibels	=	10 to 1						10
9 ,,	=	10	×	4/5	=	8	to 1	7·943/1
8 ,,	=	8	×	·8	=	6·4	to 1	6·31/1
7 ,,	=	6·4	×	·8	=	5	to 1	5·012/1
6 ,,	=	5	×	·8	=	4	to 1	3·981/1
5 ,,	=	4	×	·8	=	3·2	to 1	3·162/1
4 ,,	=	3·2	×	·8	=	2·5	to 1	2·512/1
3 ,,	=	2·5	×	·8	=	2	to 1	1·995/1
2 ,,	=	2	×	·8	=	1·6	to 1	1·585/1
1 ,,	=	1·6	×	·8	=	1·25	to 1	1·259/1

From this table we can now write at once—

11 decibels	=	12·5	to 1
12 ,,	=	16	to 1
13 ,,	=	20	to 1
14 ,,	=	25	to 1
24 ,,	=	250	to 1
34 ,,	=	2500	to 1 and so on,

and it is of course easy to remember that 20 decibels = 10^2 = 100 ; 30 decibels = 10^3 = 1,000, etc.

The above values while only approximate are quite near enough for all practical purposes.

C. E. RICKARD.

Marconi House,
Strand, W.C. 1.
March 11th, 1931."

MARCONI SHORT WAVE TRANSMITTER

TYPE T.N.19

In THE MARCONI REVIEW *for July,* 1930, *an article appeared describing the Type S.*100 *series of short wave transmitters. This series has recently been modified, and is now available under the type-title of T.N.*19.

*The T.N.*19 *series of transmitters whilst retaining all the desirable points of the S.*100 *series, represent a distinct improvement over the earlier type, as will be seen from the following description.*

THE Marconi Type T.N.19 transmitters have been designed as compact low power short wave telegraph or telephone sets, suitable either for permanent installation in submarines, vehicles, etc., or at a fixed point. The waverange of the transmitter is 15/75 m., and the sets are available in the following combinations:

T.N.19A Complete telegraph-telephone driven transmitter.
T.N.19B Driven telegraph transmitter.
T.N.19D Modulator Unit for use with T.N.19B.

A photograph showing the T.N.19A driven transmitter arranged for either telegraphy or telephony is given in Fig. 1. It will be seen to consist of two separate units, that on the left being the modulator unit, and that on the right the main transmitter unit incorporating the drive and magnifier circuits.

Telephone Modulator Unit.

A circuit diagram of the Modulator System is given in Fig. 2, and the unit consists of a screened brass container 26 inches high by 12 inches wide by 12¾ inches deep.

The purpose of this modulator panel is to provide :—

(A) Telephony.
(B) I.C.W. telegraphy on one of three chosen note frequencies.

The valve used in this panel is one M.T.12A type transmitting valve which is connected to a change-over switch shown on the bottom right-hand corner of the modulator unit. With this switch to the right, *i.e.*, in I.C.W. position, the M.T.12A valve is connected in circuit as a low frequency oscillator, the valve being thrown over to a tuned low frequency oscillating circuit instead of to the speech choke and microphone transformer. By means of a single-pole three-point note selector switch, shown in Fig. 1, placed centrally between the meters on the panel, the period of the low frequency oscillating circuit can be modified allowing for a transmission of I.C.W. on one of three different frequencies.

The measuring instruments shown on the modulator unit are the filament voltmeter on the right of the note selector switch, and the feed milliammeter to the left of the switch. Directly below the note selector switch is the filament rheostat control for the modulator valve.

A three-contact solenoid relay working from the filament supply is situated inside the modulator unit to the left of the valve. This relay provides a means of remotely controlling the change-over from C.W. telegraphy to telephony or I.C.W. working. When transmitting on telephony the valve in the modulator unit is switched over to the speech choke and microphone transformer. This is done by the Telephony/I.C.W. switch shown in the bottom right-hand corner of the modulator unit.

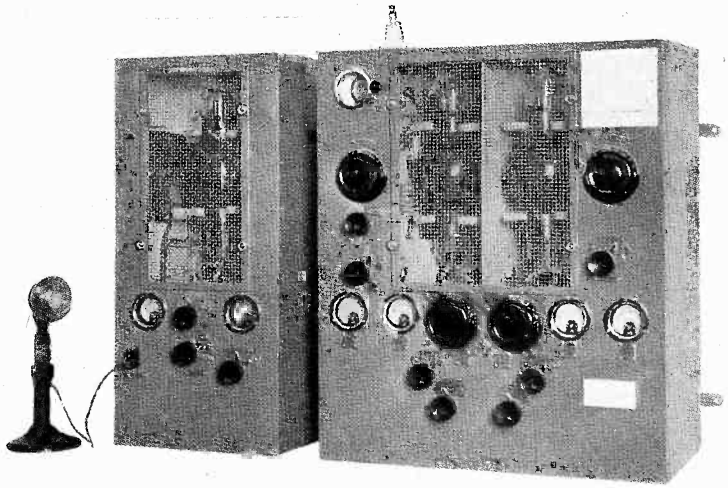


FIG. 1. *T.N.19a Transmitter.*

Transmitter Unit.

This, as shown on the right-hand side of Fig. 1, is completely enclosed in a metal box with all controls and measuring instruments on the front of the panel. All repairs can be effected from the front of the unit the design being such that the front metal panels can be easily removed.

It will be seen from the circuit diagram given in Fig. 3, that the two M.T.12A valves are used, one for the drive and one for the magnifier circuits. The H.T. supply of 2,500 volts D.C. is taken on to the magnifier anode direct, the drive valve being fed through two 30,000 ohm resistances in parallel.

The whole of the drive portion of this transmitter is shown in the right-hand portion of the Transmitter Unit, while the magnifier valve and its associated circuits are shown in the left-hand portion of the Transmitter Unit. There is a definite screening partition between the two portions, *i.e.*, Drive and Magnifier.

The wave changes of the drive circuits are effected by means of a special inductance tapping switch and a slow motion variable condenser control, shown on the right-hand portion of the transmitter unit. A small variable condenser is used as a means of coupling the drive circuit to the grid of the magnifier valve.

The magnifier circuit wave changes are effected by means of a vernier condenser and an inductance switch similar to those used on the drive portion. These controls are shown on the left-hand side of the Transmitter Unit.

A neutrodyne condenser has its control situated on the front of the Transmitter Unit, to the left of the coupling condenser control knob.

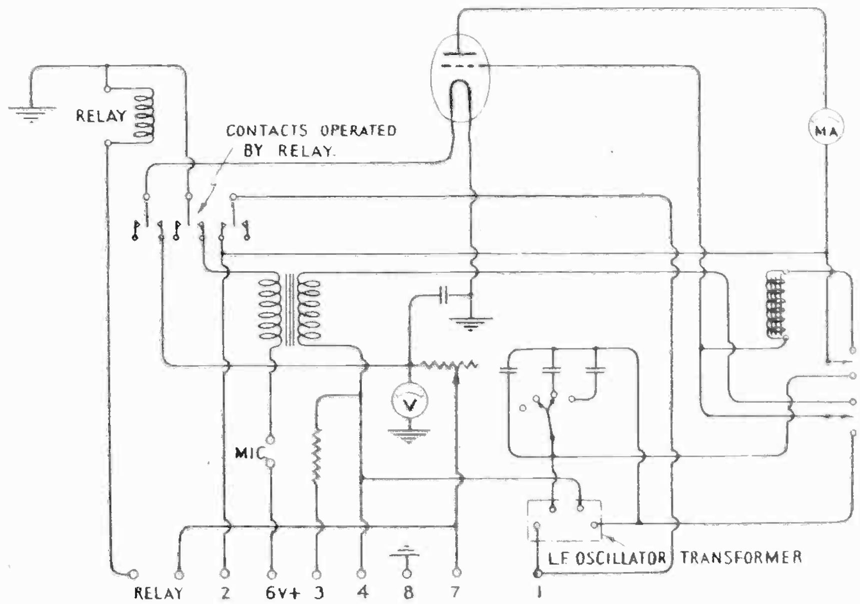


FIG. 2.

In addition to this neutrodyning condenser, the following are supplied for the purpose of neutrodyning :—

(A) An H.T. switch near the bottom of the unit.

(B) A Hot Wire Ammeter.

(C) A Push Switch fitted to the upper left hand of the Transmitter Unit.

An aerial tapping switch with five selected positions is provided and fitted below the magnifier tuning condenser. This switch is intended to provide a sufficient variation of coupling of the transmitter to the aerial system.

Each of the drive and magnifier valves is provided with a filament rheostat, and a filament voltmeter with change-over switch enables readings of the filament voltage of each valve.

The method of neutrodyning is as follows. With the aerial disconnected and the circuits, both drive and magnifier, adjusted in accordance with the wavelength table shown on the top right-hand corner of the magnifier is pressed. H.T. from the machine is then applied and on pressing the transmitting key the drive valve should oscillate. Provided the wavelength of the drive valve is correct, and this can be checked by the wavemeter supplied, the magnifier circuits should then be brought into correct tuning with the drive circuits by adjustment of the magnifier tuning condenser.

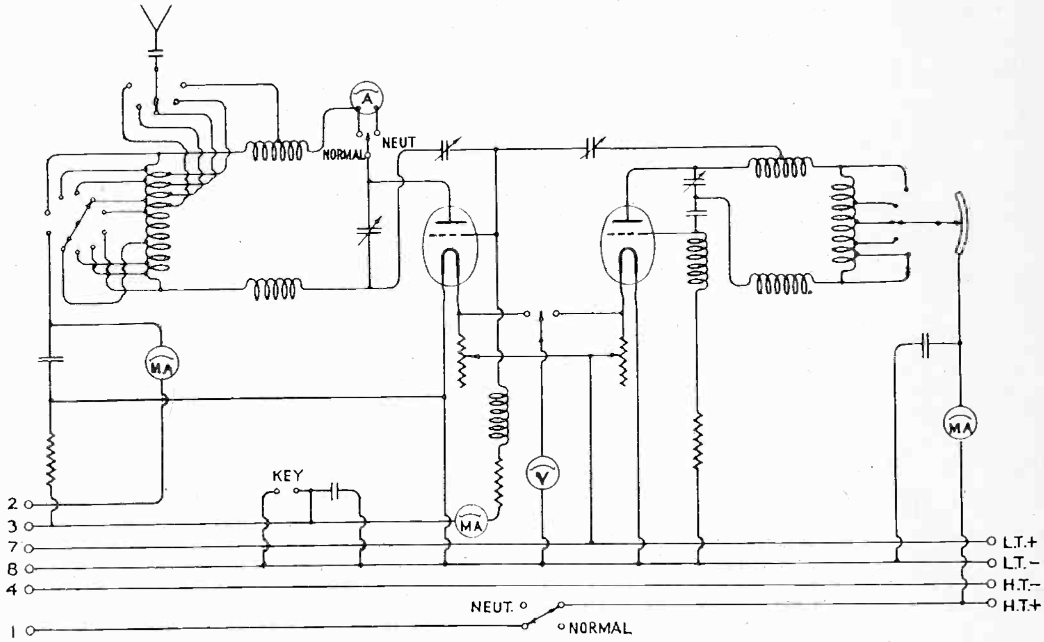


FIG. 3.

The neutrodyne condenser is now adjusted so that the reading on the meter is zero. In this condition the transmitter is now balanced for the particular wavelength being transmitted, and the connections should be made for normal working Transmission on pure C.W. can now be carried out in the normal way.

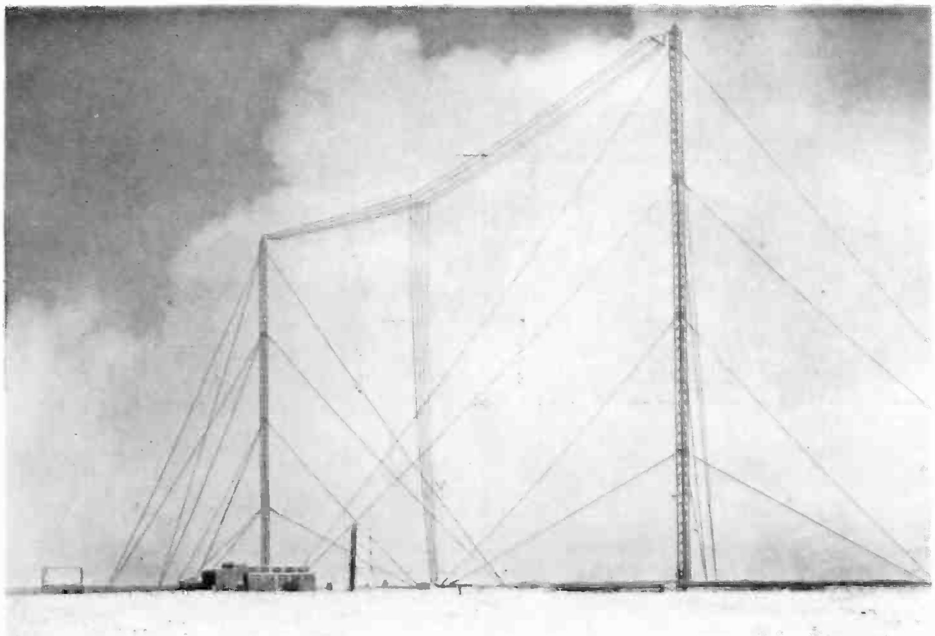
The method of keying consists of simultaneously interrupting the grid filament circuit of both the magnifier and drive valves, and also the negative of the high tension to earth.

Power Supply.

The power supply, *i.e.*, H.T. to the valve anodes and L.T. for valve filament supply, for this set is drawn from separate generators which are coupled to a motor-wound to suit the available electric supply on the submarine. The H.T. generator delivers D.C. H.T. at 2,500 volts, while the L.T. generator delivers 16 volts. The accumulator battery of 14 volts is normally floated across the L.T. generator.

MARCONI NEWS AND NOTES

POLISH BROADCASTING SUCCESS



A general view of the masts and aerials of the Marconi high-power broadcasting station at Rasin near Warsaw.

THE Marconi broadcasting transmitter at Rasin, near Warsaw, which was fully described in THE MARCONI REVIEW, No. 25, has now been put into operation by the Polish Broadcasting Company and has proved an outstanding success both in range and quality of transmission.

The station has been clearly received all over Europe and many other parts of the world. More than 700 reports from British listeners in all parts of England, Scotland, Wales, Ireland and the Channel Islands, provide a sufficient indication of the success of the station from the point of view of the distant listener.

The following brief extracts indicate the tenor of the reports received :—

> " Reception brilliant and without fault. Another advance—a splendid achievement—by the firm which stands for everything that is good in wireless."

"Strongest and clearest I have had of a foreign station."

"Reception absolutely perfect, as clear as London. Purity most marked; no fading."

"It sounded like the English National Programme until I heard the announcer say it was the Marconi Station near Warsaw."

"Magnificent is the only word that correctly defines the reception. Of all the British and foreign stations we are able to get we have never heard anything so plainly."

"Strength exceptionally good, no fading, quality better than anything heard in ten years experience."

"I have never received a station on high wavelength with such volume. At the same time quality was extremely good with absolute freedom from fading."

That the eastward range of the station is no less remarkable is shown by its inclusion under the heading "Important new broadcasting stations heard in February" in the *Ceylon Radio Times* of March, with the comment that the Warsaw station was "received at wonderful volume and with splendid modulation." To indicate this station's remarkable range it is only necessary to remark that the station is approximately 4,500 miles distant from Colombo, and that it is not working on short waves but on the wavelength of 1,114 metres, with a power of 158 kw. (C.C.I.R.).

The Complete Scheme.

The second high-power Polish broadcasting station, at Lwow, was opened in March, and has also proved highly popular with listeners in Poland and many other countries on account of its strength and clarity.

The station at Lwow is of the Marconi P.A.6 Type, and, as in the case of the Warsaw transmitter, is operated on the principle of low power modulation. The power of the transmitter is 16 kw. of unmodulated carrier energy; it may be modulated up to 80 per cent., and the C.G.I.R. rating is therefore 21 kw.

The station operates on a wavelength of 381 metres.

The third Polish high-power broadcasting station is now under construction at Wilno, and the construction of three local relay stations is to be begun in the near future. This will complete the reorganisation of the Polish broadcasting system.

The outstanding success already attained by the Warsaw and Lwow stations clearly demonstrates that when the final plan is completed Poland will be in possession of a broadcasting service which, from a technical, cultural, and international point of view will be unsurpassed in any country in the world.

Lighthouse Wireless Telephone.

A FURTHER interesting example of the utility of the Marconi fixed wavelength telephone apparatus is the equipment, with this type of apparatus, of the Smalls Lighthouse, off the coast of Pembroke, South Wales, to the order of Trinity House, to enable the men on duty to keep in touch with the shore.

The wireless telephone in the lighthouse will be as simple to operate as the ordinary domestic telephone, the turning of a switch making the apparatus instantly available for transmission or reception. A call bell is also to be installed, operated by wireless, so that the lighthouse keepers can be summoned to the telephone at any time without the necessity of maintaining a regular wireless watch.

For the shore end of the service, similar equipment, with a wireless call bell, is being installed at St. David's Head, Strumble, South Wales, the nearest convenient point on the British mainland.

Known as the Marconi Type X.M.B.1a equipment, the telephone sets employed comprise a combined transmitter and receiver operating on a fixed wavelength. This is determined in advance and the apparatus is adjusted permanently at the time of its installation. The transmitters are of 100 watts power, the energy being derived from wind-driven generating plant.

First Marconi Station in the United States.

HISTORICAL data often take time to verify and we make this our excuse for having at this later date to amend in certain important particulars the account received from New York which we published on pages 30—32 of our issue of December, 1930, of the early history of the Babylon and Seagate stations.

The first Marconi land station in the United States was erected at Navesink Lighthouse, near Sandy Hook, New York Harbour mouth, in September, 1899, for reporting the America Cup Yacht Races and was a commercial venture paid for by the *New York Herald* although dismantled when the races were finished.

The next Marconi land station in the United States was erected in August, 1901, at Siasconsett, Nantucket Island, to work with a Marconi Station installed on the Nantucket Lightship to report passing ships to the *New York Herald*. This station was worked for many years reporting shipping and handling passengers' Marconigrams. Also at the same time that Siasconsett was being started, two temporary stations were erected by the Marconi Company at Navesink again and at Long Beach and reported the America Cup Yacht Races of 1901 for the *New York Times*.

Later, in July, 1902, another coast station was erected at Sagaponack, Long Island, for communication with ships nearer New York than Nantucket Lightship.

Babylon followed in November, 1902, for communicating with ships still nearer New York.

Finally, at Seagate, a station was erected to make the last communication with ships before docking or first after leaving.

The shack used as the Wireless Station at Babylon, Long Island, therefore, which was referred to in our December issue, dates from 1902.