THE

RADIO REVIEW

A MONTHLY RECORD OF SCIENTIFIC PROGRESS IN RADIOTELEGRAPHY AND TELEPHONY

VOL. II MAY, 1921 No. 5

Editor:
PROFESSOR G. W. O. HOWE, D.Sc., M.I.E.E.

Assistant Editor:
PHILIP R. COURSEY, B.Sc., A.M.I.E.E.

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Editorial.

The paper by Commander Pession of the Italian Navy which we publish in this issue is closely allied with that by his colleague Professor Vallauri which was completed in our last issue. The two form a valuable contribution to our knowledge of the subject of radiation measurement. Doubtless measurements of a similar character will be made on all transmitting stations of any importance. Although not yet published we know that much work of a similar nature has been done by other workers. In 1913 we determined the effective resistance of the aerial at the City and Guilds Engineering College by means of a Duddell thermogalvanometer and inserted resistance, using long dashes from the Eiffel Tower as the source of power. We also worked out and communicated to the International Committee at Brussels the field strength of the Eiffel Tower signals in London, assuming effective heights for the two aerials.

The Effect of the Heaviside Layer.—In the current issue we publish the concluding portion of Mr. Eckersley's paper on this subject, the first part of which appeared in the February issue. In our opinion this paper constitutes one of the most important contributions yet made to this difficult but interesting subject. It goes far to explain the abnormal phenomena observed in connection with direction finding by means of wireless telegraphy and makes it highly desirable to carry out systematic experiments to check Mr. Eckersley's conclusions. In justice to the author, and to those readers who would have welcomed a more detailed mathematical investigation of the points raised, we should mention that at our request Mr. Eckersley has omitted a considerable portion of the more mathematical part of the paper.

The Solar Eclipse.—During the recent solar eclipse, observations of the strength of signals and atmospherics were made by a number of stations under the direction of the Post Office. We are pleased to be able to publish the result of these observations in this issue. The general effect seems to have been a partial return to night conditions. It would be of interest to learn if any other observers, especially those engaged in long distance work, noted any changes in signal strength.

Increase in Price of the "Radio Review."—When the RADIO REVIEW was first published the cost of everything connected with printing and publishing was very high, but it was anticipated that we had then reached the peak of the curve and that costs would gradually fall. These hopes have unfortunately been falsified and costs have continued to rise. We are therefore reluctantly compelled to increase the price of the RADIO REVIEW. We feel sure however that after due consideration and a comparison of present and pre-war values our readers will agree that the increase is not an unreasonable one. The new price will take effect with the June issue.

Nauen and Togoland.—Although the article with this title, the translation of which we complete in this issue, deals largely with the brief but striking history of the Togoland Station of Kamina, it contains much of wider interest. The German plans for the development of an imperial chain and the details of the financial arrangements made between the German Government and the Telefunken Company for the erection of the stations are discussed with apparent frankness. It is stated in the current number of *Radioélectricité* that the tropical vegetation has all but obliterated the traces of the Kamina Station.

Eclipse of the Sun, April 8th, 1921. Effects Produced at Wireless Stations.

By F. ADDEY, B.Sc.

In order to observe if any abnormal phenomena were produced during the eclipse, arrangements were made for a special watch to be kept at certain of the wireless stations under the control of the Post Office. The stations concerned were Wick, Stonehaven, Cullercoats, Caister, North Foreland, Niton, Lands End, Fishguard, Seaforth and Devizes.

The total period of the eclipse, at Greenwich, was from 7.35 a.m. to 10.5 a.m., G.M.T. The maximum occurred there at 8.47 a.m. At other places the times of first and last contact and of maximum were different, but these differences were so small that as far as the observations recorded below are concerned, they may be neglected.

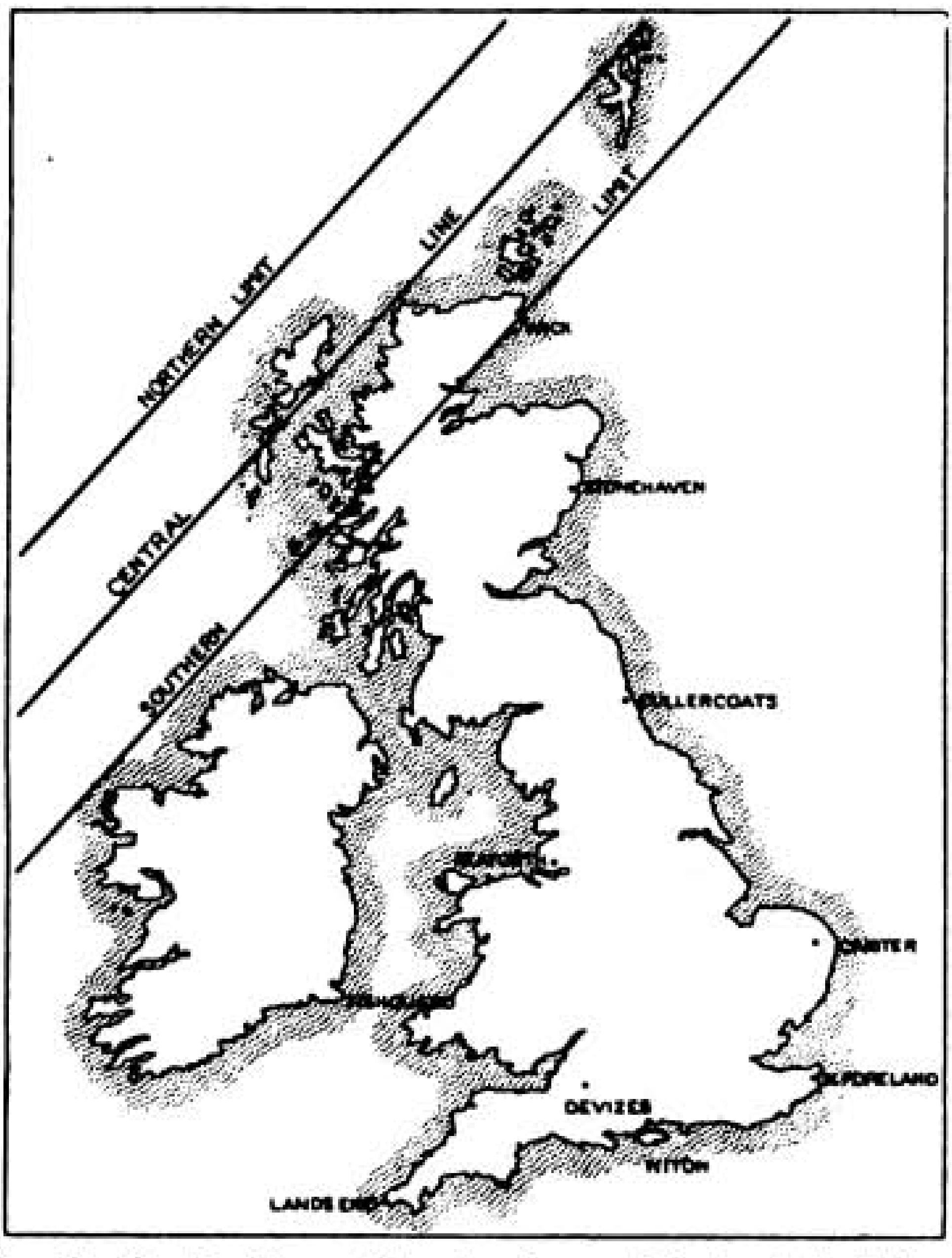
At most of the stations dealing with the ordinary ship-and-shore communication on 600 metres, no change, either in the strength of signals or in the strength or frequency of atmospherics, was observed. At Fishguard, however, between 8.28 a.m. and 9.36 a.m., signals improved both in clearness and strength. This effect was more pronounced with the signals from distant stations than with those from nearer stations.

At Wick, although no unusual daytime ranges were observed, there was during the period of the eclipse a pronounced under-current of faint signals which is not normally present during the day.

At Devizes the conditions observed during the eclipse were practically identical with those usual during the night. With a receiver consisting of one high frequency amplifier, a rectifying valve, and two note magnifying valves, the average strength of signals from Warsaw during the day is 7. Warsaw works on a wavelength of 2,100 metres, using spark transmission. During the eclipse these signals increased to maximum strength, which is the usual night condition, and after the eclipse they returned to their normal daylight strength.

Devizes also observed an increase in the strength of signals received from various French military wireless stations. These stations were working on a wavelength of about 2,000 metres, using continuous waves.

An increase in atmospherics was observed at several stations during the eclipse.



Map showing Positions of the Stations and Path of the Eclipse.

Before the eclipse atmospherics were practically absent at all the observing stations. At Fishguard slight atmospherics were observed between 8.20 a.m. and 9.36 a.m. At Devizes atmospherics came on at the commencement of the eclipse, and ceased when the eclipse was over.

At Wick atmospherics gradually became louder and more numerous during the eclipse till at about 8.56 a.m. there was a continuous crackle. This then decreased and after the eclipse the atmospherics disappeared.

A similar growth in the number and strength of atmospherics was observed at Caister, and there also the atmospherics disappeared after the eclipse.

S 2

The Measurement of the Effective Height of Aerials: a Special Case.

By Commander G. PESSION.

1. In the practice of radiotelegraphy the determination of the effective height of an aerial must now be regarded as a normal measurement. Such measurements are valuable for the rational design and modification of the aerial with respect to the characteristics of the H.F. generating plant, and, if repeated periodically, afford a control of the condition of the station.

To make the determination one measures the current received in a coil aerial of known dimensions, situated at a certain distance from the transmitting aerial. This distance should be such that absorption effects are negligible, but not so small that direct induction is appreciable.

From the theory of Hertz we have

$$hh_r = \frac{I_r}{I} \cdot \frac{d \cdot R \cdot \lambda}{120\pi} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

in which h = effective height of transmitting aerial in kilometres.

h_r = effective height of receiving aerial in kilometres.

d = distance between stations in kilometres.

λ = wavelength in kilometres.

I = current in transmitting aerial in amperes.

I_r = current in receiving aerial in amperes.

R = total resistance of receiving circuit in ohms.

In a frame or coil aerial we can put

$$h_r = 2\pi \frac{S_r}{\lambda} \cos \alpha$$

where S_r = total effective area of receiving coil in m^2.

α = angle between the vertical plane of the coil and the vertical plane through the two stations.

Substituting this in (1) we get

$$h = \frac{I_r}{I} \cdot \frac{dR\lambda^2}{240\pi^2 S_r \cos \alpha} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

Equations (1) and (2) refer to the now general case of undamped waves.

The measurement of I_r can be made with a thermogalvanometer or with a thermocouple connected to a suitable galvanometer.

2. To verify the effective height of the Italian Naval Station at Rome, I have used a simple method which I think is worthy of description since it may be found very useful when one has a sufficient number of stations in the vicinity. This will generally be the case at a naval base, where there are always several ships furnished with wireless apparatus and usually a powerful coast station.

If one has three stations A, B, C, and if the suffixes a, b, c, be used to distinguish symbols referring to the respective stations, we have when A transmits to B

$$h_a h_b = \frac{I_r}{I} \frac{\lambda_a d_{ab} R_b}{377} \quad \ldots \ldots \ldots \ldots (3)$$

when B transmits to C

$$h_b h_c = \frac{I_r}{I} \frac{\lambda_b d_{bc} R_c}{377} \quad \ldots \ldots \ldots \ldots (4)$$

and when C transmits to A

$$h_c h_a = \frac{I_r}{I} \cdot \frac{\lambda_c d_{ca} R_a}{377} \quad \ldots \ldots \ldots \ldots (5)$$

From these three equations we can determine the three unknowns h_a, h_b, h_c.

3. With the power and distance of the Rome Station the measurements can be made very simply by means of a Duddell thermogalvanometer.

The measurement of the resistance was made by introducing step by step into the accurately tuned aerial a known resistance R'; then

$$R = R' \frac{I_r'}{I_r - I_r'}$$

in which I_r is the received current without the inserted resistance R' and I_r' that with it.

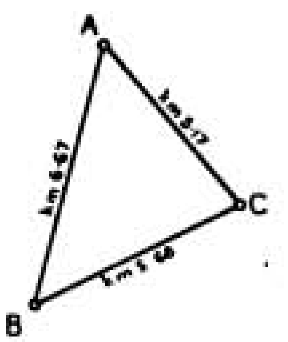


FIG. 1.

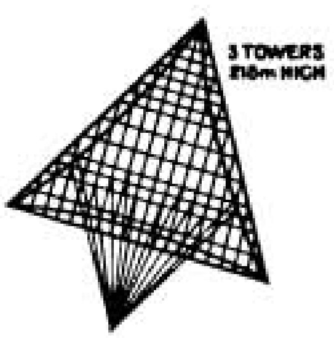


FIG. 2.

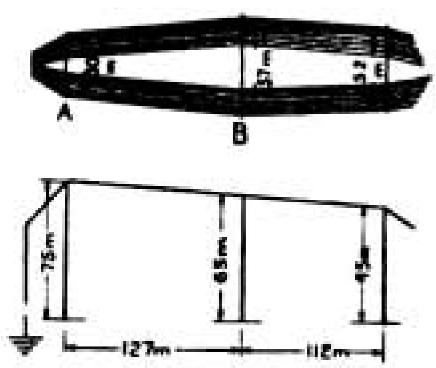


FIG. 3.

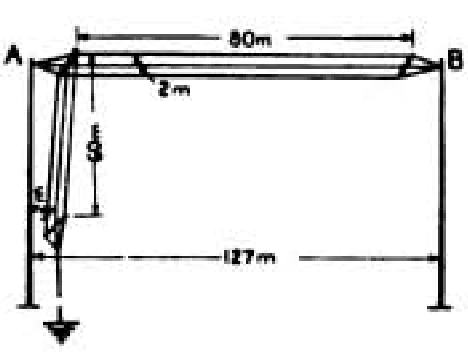


FIG. 4.

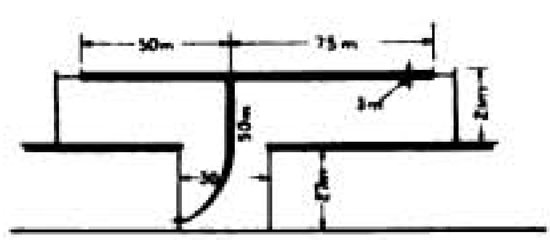


FIG. 5.

Fig. 1 shows the distances between the three aerials (measured to their centres), while Figs. 2, 3, 4 and 5 show their construction and principal dimensions.

1st Test.—Transmitting from B to A.

$I_r = 95 \cdot 10^{-3}$ A. $I = 18 \cdot 0$ A. $\lambda = 3 \cdot 2$ km.

$R = 12 \cdot 72$ ohms. $d = 6 \cdot 67$ km. $h_a h_b = 0 \cdot 0038$.

The following series of readings shows the reliability of the readings.

	I_r	I_r'
	95·3	78·1
	95·5	77·7
	95·0	78·0
	95·2	77·8
	95·0	77·6
	94·8	77·7
	94·7	77·5
Means :	95·1	77·8

$R' = 2 \cdot 83$.

$$R = 2 \cdot 83 \frac{77 \cdot 8}{17 \cdot 3} = 12 \cdot 72.$$

2nd Test.—Transmitting from C to A.

$I_r = 49 \cdot 10^{-3}$ A. $I = 10 \cdot 6$ A. $\lambda = 3 \cdot 15$ km.

$R = 12 \cdot 90$ ohms. $d = 5 \cdot 17$ km. $h_c h_a = 0 \cdot 00257$.

3rd Test.—Transmitting from C to B.

$I_r = 24 \cdot 5 \cdot 10^{-3}$ A. $I = 13 \cdot 0$ A. $\lambda = 1 \cdot 8$ km.

$R = 10 \cdot 30$ ohms. $d = 5 \cdot 68$ km. $h_c h_b = 0 \cdot 000526$.

From which

$h_a = 136$ m ; $h_b = 27 \cdot 9$ m ; $h_c = 18 \cdot 8$ m.

It is interesting to note that Station C has a **T** aerial erected above a large factory, the actual height of the horizontal portion above the roof being about 20 metres. Station B has two aerials, a large and a small ; the measurements were made on the small one. A fourth test using the large aerial gave the following results :—

$h_b' = 40 \cdot 3$ m with the small aerial insulated.

$h_b' = 35 \cdot 6$ m with the small aerial put to earth.

4. Another test was made after the small B aerial had been modified. Station C was not employed, but a temporary aerial was erected with a length of about 200 metres and a height of about 10 metres ; it was situated at a distance

$d = 19 \cdot 6$ km from A

and $d' = 24 \cdot 7$ km from B.

A Duddell thermogalvanometer was employed with the following results :—

Transmitting from A

$I = 54$ A; $I_r = 0{\cdot}212{\cdot}10^{-3}$ A; $R = 585$ ohms; $\lambda = 6{\cdot}08$ km.

Transmitting from B

$I' = 20$ A; $I_r' = 0{\cdot}1428{\cdot}10^{-3}$ A; $R' = 155$ ohms; $\lambda = 2{\cdot}40$ km.

The above values of R were obtained with a 100 ohm heater and in the case of A, an additional 400 ohms was inserted to reduce the current.

From the above it can be seen that

$$\frac{h_a}{h_b} = \frac{I_r I' \lambda_a d}{I_r' I \lambda_b d'} \cdot \frac{R}{R'} = 4{\cdot}14.$$

By transmitting from B to A the following results were obtained:—

$I_r = 92{\cdot}10^{-3}$ A; $I = 18$ A; $d = 6{\cdot}67$ km.

$R = 15{\cdot}4$ ohms; $\lambda = 3{\cdot}15$ km; $h_a h_b = 0{\cdot}00439$ km^2.

Hence $h_a = 135$ m and $h_b = 32{\cdot}6$ m.

In this test a resistance of 3 ohms was inserted in the A aerial to reduce the received current; the real value of the antenna resistance was therefore 12·4 ohms which agrees very well with the value 12·7 ohms previously determined. The difference is to be attributed to the different inductances employed for tuning in the two tests, which moreover took place with an interval of four months. In these tests a Duddell thermogalvanometer with a heater of 1·77 ohms was inserted in the antenna. One sees that as a consequence of the alterations to aerial B its effective height has been increased.

The two determinations of h_a are in perfect agreement and correspond closely with the value of 138 m determined three years ago by Prof. Vallauri by direct measurement on a coil aerial.

The Effect of the Heaviside Layer on the Apparent Direction of Electromagnetic Waves.

By T. L. ECKERSLEY, B.A., B.Sc.

(*Concluded from page 65 of February issue.*)

We will choose rectangular axes, the axis of z perpendicular to the plane of the earth, the axis of x in the direction of the ray, and the axis of y in the horizontal plane perpendicular to the ray. The following symbols will be used throughout the paper:—

$\left.\begin{matrix} X \\ Y \\ Z \end{matrix}\right\}$ = Electric forces in the x, y, z directions respectively.

$\left.\begin{matrix} \alpha \\ \beta \\ \gamma \end{matrix}\right\}$ = Magnetic forces in the x, y, z directions respectively.

α = Re-combination constant.

$\left.\begin{array}{l} l, n \\ l, -n \\ l', n' \end{array}\right\}$ = Direction cosines of the normals to the wavefronts of rays (2), (3) and (4).

E = E.M.F. induced in a closed circuit.

K' = Specific inductive capacity of earth.

μ = Permeability of earth.

σ = Conductivity of earth.

$\nu = 2\pi/\lambda$.

λ = Wavelength.

c = Velocity of light.

$p = 2\pi \times$ frequency of the electric waves.

The suffixes are explained in the course of the paper.

The following rays are considered (Fig. 4), and for convenience are named as follows :—

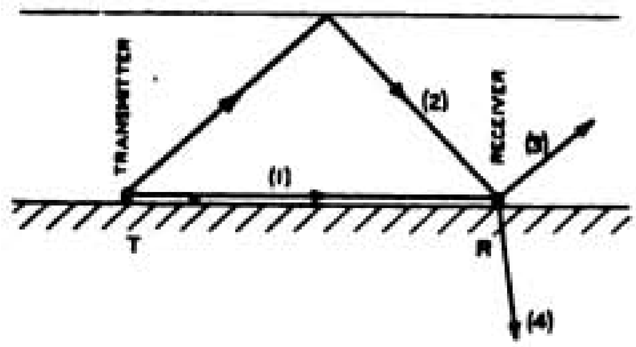


FIG. 4.

No. (1) is called the "direct ray."

No. (2) is called the "incident ray."

No. (3) is called the "reflected ray" (at the surface of the earth).

No. (4) is called the "refracted ray" (in the earth).

A wave is to be considered as polarised in the plane of its electric force. In general there will be two waves polarised in perpendicular planes :

(a) With the electric force in a vertical plane perpendicular to the earth, in which case $\alpha = \gamma = Y = 0$.

(b) With the electric force parallel to the surface of the earth, in which case β, X and Z are all zero.

Case (a) may be excluded from consideration as $\alpha = 0$, which means that there is no magnetic force in the direction of the ray.

In general there will be only three rays to consider at the receiving station : (1) the incident ray, (2) the reflected ray, and (3) the refracted ray.

These are :—

$$\left.\begin{array}{lll} \text{Incident ray.} & \text{Reflected ray.} & \text{Refracted ray.} \\ Y = Y_0\epsilon^{j\nu(lx + nz - ct)} & Y = Y_r\epsilon^{j\nu(lx - nz - ct)} & Y = Y'\epsilon^{j\nu'(l'x + n'z - ct)} \\ \alpha = \alpha_0\epsilon^{j\nu(lx + nz - ct)} & \alpha = \alpha_r\epsilon^{j\nu(lx - nz - ct)} & \alpha = \alpha'\epsilon^{j\nu'(l'x + n'z - ct)} \\ \gamma = \gamma_0\epsilon^{j\nu(lx + nz - ct)} & \gamma = \gamma_r\epsilon^{j\nu(lx - nz - ct)} & \gamma = \gamma'\epsilon^{j\nu'(l'x + n'z - ct)} \end{array}\right\} \quad . \quad (1)$$

Now in the upper medium, *i.e.*, the air above the surface of the earth, the total electric force is :—

$$Y = \epsilon^{j\nu(lx - ct)}\,(Y_0\,\epsilon^{j\nu nz} + Y_r\,\epsilon^{-j\nu nz})$$

$$\text{or } Y = \epsilon^{j\nu(lx - ct)}\,\{(Y_0 + Y_r)\cos\nu nz + j\,(Y_0 - Y_r)\sin\nu nz\} \quad . \quad . \quad (2)$$

Now an application of the laws of metallic reflection shows that in this case

$$(Y_0 + Y_r) = \frac{2nY_0}{\left(\frac{n}{\mu'} + \frac{S}{\mu'} + \frac{jS'}{\mu'}\right)} \text{ and } (Y_0 - Y_r) = \frac{2Y_0\left(\frac{S}{\mu'} + \frac{jS'}{\mu'}\right)}{\left(\frac{n}{\mu} + \frac{S}{\mu'} + \frac{jS'}{\mu'}\right)} \quad . \quad . \quad (3)$$

Where

$$S = -\frac{1}{\sqrt{2}}\left\{R + (\mu'K' - 1) + n^2\right\}^{\frac{1}{2}} \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

$$S' = -\frac{1}{\sqrt{2}}\left\{R - (\mu'K' - 1) - n^2\right\}^{\frac{1}{2}} \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

$$R = \left[\left\{\left(\mu'K' - 1\right) + n^2\right\}^2 + \frac{\sigma^2\mu'^2}{\nu^2}\right]^{\frac{1}{2}} \quad . \quad . \quad . \quad . \quad . \quad (6)$$

μ' permeability of the earth.
K' specific inductive capacity of the earth.
σ specific conductivity of the earth.

Now

$$-\mu\frac{\partial\alpha}{\partial t} = \frac{\partial Y}{\partial z} = \epsilon^{j\nu(lx - ct)}\left\{-(Y_0 + Y_r)\nu n \sin \nu nz + j(Y_0 - Y_r)\nu n \cos \nu nz\right\}. \quad (7)$$

remembering the values of $(Y_0 + Y_r)$ and $(Y_0 - Y_r)$ we see that when n is small the latter term is the most important, the former being of the order n^2 and the latter of the order νn. In any case the expression vanishes with n so that when the wave is propagated parallel to the surface of the earth there is no flux α and no E.M.F. induced in a loop in the yz plane (as before stated).

We may therefore infer from the experimental existence of this E.M.F. that "n" is not zero (excluding the ray reflected in the horizontal plane for the reasons before stated), *i.e.*, that there is a ray which makes an appreciable angle with the surface of the earth. The argument of course only refers to plane waves propagated over a plane surface, but the argument is obviously true to the first order where the radius curvature of the wave front is large compared with the wavelength (and such are all the cases met with in practice).

EXPERIMENTAL TEST FOR THE RAY REFLECTED IN A VERTICAL PLANE, AND POLARISED IN HORIZONTAL PLANE.

The experiment consists in isolating this ray and comparing its intensity with that of the direct ray, at the same time noting the error in the bearing. In order to do this a closed horizontal receiving aerial was used.

It follows from the previous analysis (and Sommerfeld's more general analysis *) that for a ray propagated over the surface of the earth γ the vertical magnetic force is zero, and therefore there is no flux linked with a closed aerial in a horizontal plane, and no E.M.F. can be induced in it by such a ray. But for the ray reflected in the vertical plane (which for the sake of

* *Annalen der Physik*, 28, p. 665, 1909.

brevity we shall now call the indirect ray) the E.M.F. induced is proportional to

$$-\mu\frac{\partial\gamma}{\partial t} = -\frac{\partial Y}{\partial x} = -j\nu l(Y_0 + Y_r) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (8)$$

$$= \frac{-j\nu l n\gamma_0}{\left\{\frac{n}{\mu} + \frac{S}{\mu} + \frac{jS'}{\mu}\right\}} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (9)$$

so that the E.M.F. induced is proportional to the angle of elevation of the ray when this is small and to the intensity of the ray itself.

The arrangements used for this comparison were as follows (Fig. 5) :—

TABLE I.—OBSERVATIONS MADE ON TRANSMITTING STATION AT DAMASCUS.

Date.	$\frac{1}{2}\theta_1$	tan $\frac{1}{2}\theta_1$	θ	tan θ	Remarks.
June 16th	23° G.	0·42	20° flat.	0·36	Taken at night.
"	20° G.	0·36	15° flat.	0·27	" "
June 17th	4° V.G.	0·07	0°	0	Three-day observation.
"	32° G.	0·625	20° G.	0·36	Night.
"	15° V. flat.	0·27	22° F.	0·34	"
"	27° F.	0·51	16° F.	0·29	"
"	21° G.	0·38	9° F.	0·16	"
"	18° G.	0·32	6·5° G.	0·11	"
"	16° V. flat.	0·29	1° V. flat.	0·02	"
"	19° V. flat.	0·34	0° V. flat.	0	"
" "	10° / 9° } V. flat.	{ 0·18 / 0·16 }	−4° V. flat.	0·07	"
" "	16° to 20° } fair.	{ 0·29 / 0·36 }	0° V. flat.	0	"
"	20° fair.	0·36	1° V. flat.	0·02	"
June 18th	10° to 32° varying.	0·18 to 0·625	9° G.	0·16	"
"	24° to 32°	0·445 to 0·625	24·5° flat.	0·46	"
"	25°	0·47	11° F.	0·19	"
"	15° G.	0·27	6° F.G.	0·10	"
"	6° G.	0·10	3° V.G.	0·05	"
"	12°	0·21	10° G.	0·18	"
"	9° G.	0·16	3° G.	0·05	"
"	7° G.	0·12	3° G.	0·05	"
"	5° G.	0·09	2° V.G.	0·03	"
"	6° G.	0·10	2° V.G.	0·03	"
"	8° V.G.	0·09	0° V.G.	0	"
" "	4·5° / 5·0° } V.G.	{ 0·08 / 0·09 }	0·5°	0·01	"
"	13° flat.	0·23	7° G.	0·12	"
"	15° V. flat.	0·27	11° F.	0·19	"
"	22° to 17° flat.	0·40 to 0·30	17° F.	0·30	"
"	11° flat.	0·19	5° G.	0·09	"
"	17° G.	0·30	5° G.	0·09	"

The vertical loop, consisting of a frame 5 feet 6 inches × 7 feet wound with twenty turns of bare copper wire, was placed at the centre of a closed horizontal loop (about 40 yards square and 12 feet above the surface of the ground). The terminals of the loop and horizontal aerial were each brought to the terminals of one of the fixed coils of the compass or goniometer, and the search coil of the compass was connected to the receiving apparatus. A

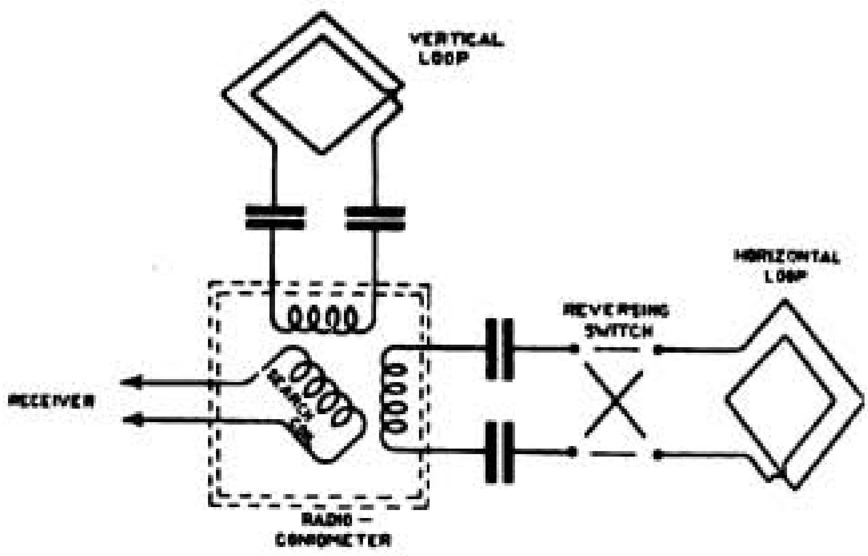


FIG. 5.

reversing switch was placed in the horizontal aerial. If the currents in the loop circuit and horizontal aerial circuit are in phase the resultant magnetic field (in the goniometer) will always lie along some fixed direction, and it will be possible to find a position of the search coil where there is no flux linkage and no signals.

Thus if θ_1 is the difference in position of the two minima when the horizontal aerial is reversed

$$\tan \tfrac{1}{2}\theta_1 = \frac{\text{current induced in horizontal aerial}}{\text{current induced in loop}} \quad . \; . \; . \; . \; . \; . \quad (10)$$

In the accompanying table (I.) this quantity $\frac{1}{2}\theta_1$ (*i.e.*, the measure of the intensity of the indirect ray) is compared with θ, the error in bearing which is taken either immediately before or after the measurement of θ_1.

The curve (Fig. 6) shows $\tan \frac{1}{2}\theta_1$ plotted against $\tan \theta$ and a glance reveals the fact that they are roughly proportional, *i.e.*, a bad bearing is associated with strong signals in the horizontal aerial. The points should not necessarily lie on a single curve as the error in bearing is only a measure of the disturbing E.M.F. when this is in phase with the main E.M.F. (When the E.M.F.'s are not in phase a slight distuning of the horizontal aerial will produce a large change of phase in the current, so that a suitable readjustment of the tuning condenser will bring the currents into phase again. The measured current in the horizontal aerial will then be slightly too small.)

The points marked in Fig. 6 with a full dot "•" are those for which the minima on the frame and the compass are both well defined. These lie fairly well on a straight line (see Fig. 7); the slope of this line (*i.e.*, $\tan \frac{1}{2}\theta_1 / \tan \theta$) should be a function of the electrical constants of the horizontal and loop aerials, and the conductivity, resistivity and inductivity of the earth.

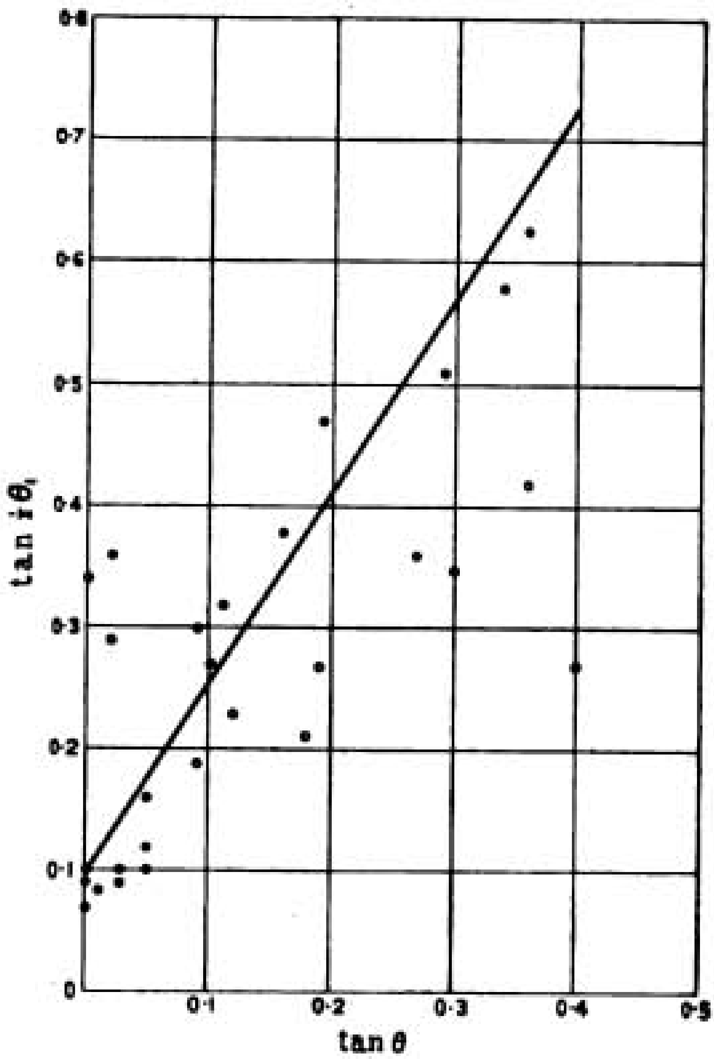


FIG. 6.

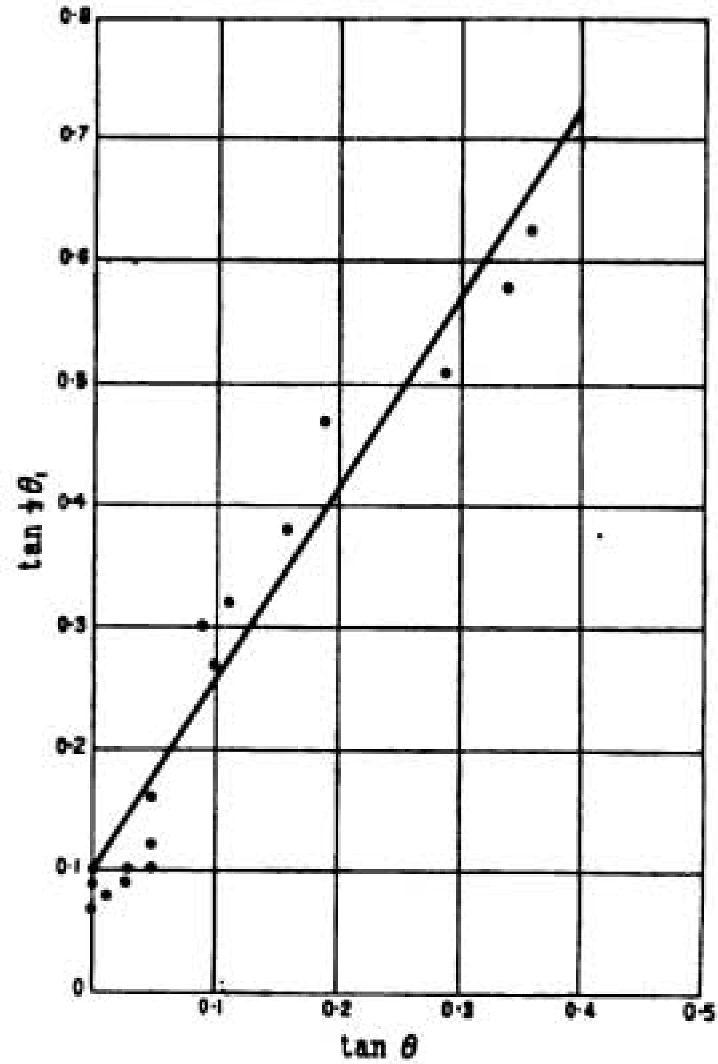


FIG. 7.

Let E_1 = the E.M.F. induced in the loop when this is parallel to the direction of the ray.

E_1' = the E.M.F. induced in the loop when this is perpendicular to the direction of the ray.

E_h = the E.M.F. induced in the horizontal aerial per unit area.

A_h = area of horizontal frame.

A_1 = area of loop × number of turns.

$E_h A_h$ = E.M.F. induced in horizontal aerial.

$E_1 A_1$ = maximum E.M.F. induced in loop.

R_h = effective resistance of horizontal aerial.

R_1 = effective resistance of horizontal loop.

Then

$$\tan\theta = \frac{E_1'}{E_1} \quad . \quad . \quad . \quad (11)$$

and at the same time

$$\tan\tfrac{1}{2}\theta_1 = \frac{E_h A_h R_1}{E_1 A_1 R_h} \quad . \quad . \quad . \quad (12)$$

so that

$$\tan\tfrac{1}{2}\theta_1/\tan\theta = \frac{E_h}{E_1'} \times \text{(constant)} \quad . \quad . \quad . \quad (13)$$

where this constant depends only on the electrical constants of the circuits.

Now E_h and E_1' depend only on the ray reflected in the vertical plane, in fact

$$E_h = -\frac{\mu\partial\gamma}{\partial t} \quad \ldots \ldots \ldots \ldots (14)$$

$$E_1' = -\frac{\mu\partial\alpha}{\partial t} \quad \ldots \ldots \ldots \ldots (15)$$

and since the ray polarised in the Y plane (Y, α, γ), can only affect these two aerials the ratio of $\partial\gamma/\partial t$ to $\partial\alpha/\partial t$, $\frac{E_h}{E_1'}$, can only be dependent on the ratio of the incident and reflected rays, *i.e.*, upon the constants of the ground and the angle of elevation of the incoming ray.

In fact, from (3),

$$E_h = -\frac{j\nu l n Y_0}{\left\{\frac{n}{\mu'} + \frac{S}{\mu'} + \frac{jS'}{\mu'}\right\}} \quad \ldots \ldots \ldots \ldots (16)$$

$$E_1' = \frac{j\nu n Y_0 2\left(\frac{S}{\mu'} + \frac{jS'}{\mu'}\right)}{\left\{\frac{n}{\mu'} + \frac{S}{\mu'} + \frac{iS'}{\mu'}\right\}} \quad \ldots \ldots \ldots \ldots (17)$$

so that

$$\frac{E_h}{E_1'} = -\frac{l}{2\left(\frac{S}{\mu'} + \frac{jS'}{\mu'}\right)} \quad \ldots \ldots \ldots \ldots (18)$$

l being practically unity

where

$$S = -\frac{1}{\sqrt{2}}\{R + (\mu'K' - 1) + n^2\}^{\frac{1}{2}}$$

$$S' = -\frac{1}{\sqrt{2}}\{R - (\mu'K' - 1) - n^2\}^{\frac{1}{2}}$$

$$R = \left[\{(\mu'K' - 1) + n^2\}^2 + \frac{\sigma^2\mu'^2}{\nu^2}\right]^{\frac{1}{2}}$$

μ', σ, K', n having the same significance as before. If E_1 and E' are in phase (*i.e.*, if a good minimum is obtained with the rotating loop) E_h and E_1 are practically 45° out of phase (since $S = S'$ approximately), if then the horizontal aerial is adjusted so as to give a good balance on the compass

$$\tan\tfrac{1}{2}\theta_1/\tan\theta = \frac{1}{\sqrt{2}}\frac{E_h}{E_1} \times C_1 = \frac{1}{\sqrt{2}}\frac{1}{2}\frac{1}{\frac{S}{\mu'} + \frac{jS'}{\mu'}} \times C_1 \quad \ldots \ldots (19)$$

$$= \frac{1}{4}\frac{1}{S} \times C \text{ nearly} \quad \ldots \ldots \ldots \ldots (20)$$

Where C is the constant $\frac{A_h R_1}{A_1 R_h}$, the quantity C can be roughly measured; we then get a rough value for S from this last equation.

The value for S so obtained was about 5, and this quantity calculated from the approximate constants of the earth is about 7, so that agreement of the right order is obtained. Only a rough agreement can be expected, firstly because of the uncertainty of phase of the various factors, secondly because of the difficulty of getting sufficiently well defined minima, and thirdly because the electrical constants of the earth are not known with any degree of accuracy.

A slight residual E.M.F. induced in the horizontal aerial remains even in the daytime. This may be due to slight tilting of the horizontal aerial, or it may represent a real residual reflection or refraction at the upper layer. There is evidence that this exists even in the daytime, for the mathematical researches of G. N. Watson indicate that the pure diffraction of waves round the earth is not sufficient to account for the observed results of Austin,* and that it is necessary to assume a reflecting layer in order to bring the theory into accordance with practical observations.

The values of tan θ will give us an estimate of the relative intensities of the reflected rays and horizontal direct ray,

for

$$\tan\theta = -\frac{\frac{\mu\partial\alpha}{\partial t}}{\frac{\partial z}{\partial x}} = -\frac{n2\left(\frac{S}{\mu'}+\frac{jS'}{\mu'}\right)}{\left\{\frac{n}{\mu}+\frac{S}{\mu'}+\frac{jS'}{\mu'}\right\}}\cdot\frac{Y_0}{Z_0} \quad . \quad . \quad . \quad . \quad . \quad . \quad (21)$$

and when n is small compared with S and S' as it always is, tan θ is very nearly $\frac{2nY_0}{Z_0}$ now Z_0 includes the electric force Z_1 in the direct ray and the electric force Z_1' in the indirect incident ray.

(Of course Z_1 and Z_1' may be 180° out of phase so that the effect of the deviating electric force is accentuated in this case, even a small amount of energy reflected will produce large effects.)

If Z_1' is zero

$$\tan\theta = \frac{2nY_0}{Z_1} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (22)$$

or

$$\frac{Z_1}{Y_0} = \frac{2n}{\tan\theta}$$

now n is of the order 0·1 and tan θ varies between 0·2 and 0·3 so that Z_1 and Y_0 are of the same order of magnitude, *i.e.*, the direct ray and indirect ray are of the same order of intensity at night.

The indirect ray (polarised in the horizontal plane, *i.e.*, with the electric force horizontal (Y, α, γ)) may be produced by radiation from an asymmetrical

* G. N. Watson, *Proceedings of the Royal Society*, 95A, p. 83, 1918; also Van der Pol, *Philosophical Magazine*, 38, p. 365, September, 1919.

inverted L type aerial, for the radiation from such an aerial in any direction, except in the horizontal plane, has a component of the electric force parallel to the horizontal portion of the aerial, so that if this transmitting aerial has the horizontal part or a component part of the horizontal part of the aerial in the yz plane, the indirect ray reflected at the upper conducting layer of the atmosphere will have a component polarised in the horizontal plane.

If the aerial is symmetrical about a vertical axis as, for instance, an umbrella type aerial, then the ray will be polarised entirely in the vertical plane (z, x, β) and therefore cannot produce any E.M.F. in the loop when this is perpendicular to the line joining it to the transmitter.

If, however, the reflecting layer is not horizontal (Fig. 8), reflection will introduce a component polarised in the horizontal plane.

Again if the conducting layer is æolotropic, an effect which might be produced by the earth's magnetic field making the conductivity different in different directions, or if there is a rotation of the plane of polarisation due to the presence of electrons in this field, this will result in the production of a reflected ray polarised in the horizontal plane even when the transmitter is symmetrical and the reflecting layer is sensibly level.

It will be seen that there are two different ways in which the bad night bearings may be produced :—

(1) An effect due to asymmetry of transmitting aerial.

(2) An effect due to the asymmetry of the Heaviside layer, due to its being tilted to one side or the other, or to its conductivity being different in different directions.

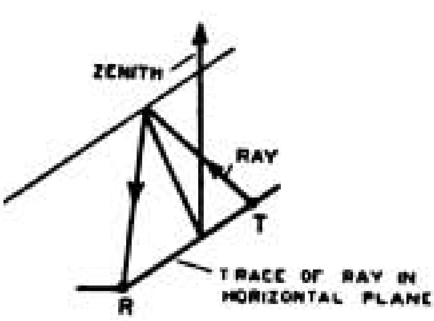


FIG. 8.

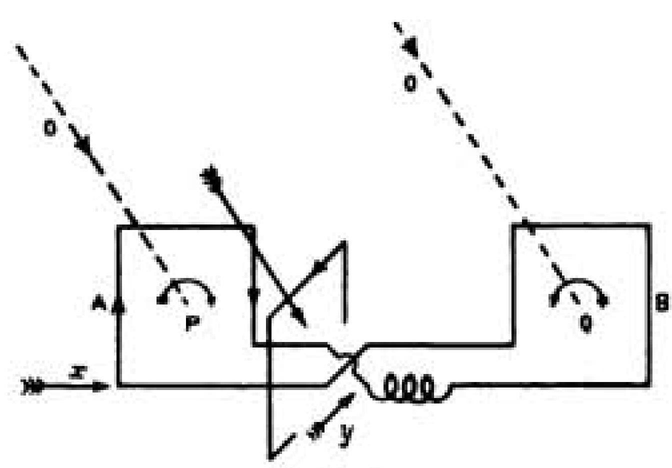


FIG. 9.

These effects may be separated by using a receiver of the following kind. A receiver is used in which each of the ordinary closed loops of the Bellini-Tosi aerial is replaced by two loops (in the same plane) connected up so that the E.M.F.'s induced in the two aerials are nearly in opposition (see Fig. 9). In this case it is obvious that a wave travelling in the plane of AB (in the x direction) will only produce an E.M.F. in the complete system on account of the difference in phase of the E.M.F. induced in A and B. A wave travelling in the yz plane will produce no E.M.F., even when the ray is tilted (as in Fig. 9) for in this case the flux linkage with each loop A and B is the same, and in the same phase. This system will therefore eliminate the effect o the ray reflected in the vertical plane (so long as this ray is entirely in the vertical plane). If, on account of reflection from a tilted reflecting layer, the ray no longer remains in the vertical plane, the length of the path of the ray OP to the frame A differs from the length of path of the ray OQ to the frame B, so that the E.M.F.'s induced at A and B will not be in phase, and a resulting E.M.F. will ensue, and the system will no longer give true bearings.

The intensity of the ray reflected in the vertical plane may seem at first sight to be rather too large, but it must be remembered that this indirect ray is not subject to the same attenuation as the direct ray, which may be intercepted by mountains or reduced by losses in travelling over the earth. In this connection the effect of mountains in reducing the direct ray in comparison with the indirect ray, and thereby increasing their errors, is particularly marked, and it is almost impossible to get good bearings in mountainous countries at night.

Another experiment to prove the existence of the indirect ray was carried out as follows (Fig. 10).

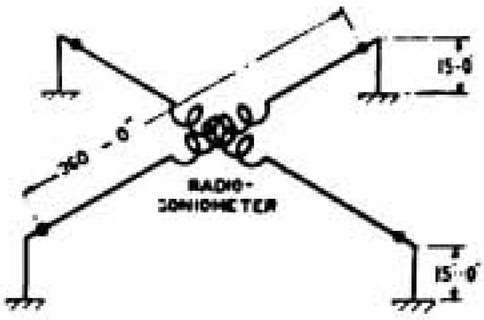


Fig. 10.

These were made with a direction finding apparatus consisting of two horizontal aerials in the place of the vertical loops. The two aerials were perpendicular and were at a level of about 15 feet above the ground, and had a span of about 120 yards. The bearings were compared with those taken on an ordinary Bellini-Tosi aerial. The receiving system was situated at Salonika and the transmitting station chosen for these experiments was the large power station at Constantinople. The mean day bearing of this station was 83° (which differs only a fraction of a degree from the true bearing). The night bearings are rather variable, but have a mean of about 89° or 90°; thus there is a systematic error of 6° or 7°. When receiving on the horizontal aerials at night the bearings of Constantinople were about 62°. Accurate check bearings were taken on other neighbouring stations at the same time so that the error was not due to instrumental faults.

We may at once infer from the bearing obtained that there must be a component of the electric force horizontal and perpendicular to the plane of propagation. This horizontal force is in the opposite sense to that which might at first sight have been expected, for it reduces the bearing instead of increasing it (as on the Bellini-Tosi aerials), but this fact is in accordance with the theory, for it can be shown by a rough calculation that the two systems of aerials, *i.e.*, the horizontal aerial and the Bellini-Tosi aerials, should give deviations in opposite directions.

This calculation can be made as follows :—

As before we will assume that the waves are approximately plane. The electric forces which are concerned in producing currents in the horizontal aerial are the following :—

(1) The horizontal electric force in the direct ray.

This will be in the plane of propagation and its intensity (compared with the vertical force in the same ray) will depend chiefly on the conductivity of the ground over which the ray passes according to the theories of Zenneck and Sommerfeld.

(2) The horizontal electric force in the ray reflected at the upper conducting layer perpendicular to the plane of propagation.

(3) The horizontal electric force in the reflected ray in the plane of propagation.

The second is the one which produces the deviation from the true bearing.

In order to get the mean value of the effect of (2) we will neglect the effect of (3). (1) and (3) may be opposed and give prominence to (2).

As before let the X axis, be the direction in which the waves are advancing, the plane $Z = 0$ the surface of the earth, then the electric force we are concerned with, and which produces the errors, is parallel to the Y axis. The electric forces in the *direct* wave are in the X and Z directions and may be expressed in the form :—

$$\left.\begin{aligned} X &= X_0 \epsilon^{j\nu n z} \epsilon^{j\nu(lx - ct)} \\ Y &= Y_0 \epsilon^{j\nu n z} \epsilon^{j\nu(lx - ct)} \\ \beta &= \beta_0 \epsilon^{j\nu n z} \epsilon^{j\nu(lx - ct)} \end{aligned}\right\} \text{ above the earth's surface. . . . (23)}$$

$$\left.\begin{aligned} X &= X_0' \epsilon^{j\nu n' z} \epsilon^{j\nu(lx - ct)} \\ Y &= Y_0' \epsilon^{j\nu n' z} \epsilon^{j\nu(lx - ct)} \\ \beta &= \beta_0' \epsilon^{j\nu n' z} \epsilon^{j\nu(lx - ct)} \end{aligned}\right\} \text{ below the earth's surface . . . (24)}$$

Where $\nu = \frac{2\pi}{\lambda}$, λ is the wavelength, and $c =$ the velocity of light. l, n, n' are so chosen as to satisfy the differential equations and the surface conditions.

The components of the incident and reflected waves have already been expressed in equations (3).

When using the horizontal aerials the angular deviation θ_1 from the true bearing is measured by the ratio of the total electric force in the y direction to that in the x direction, *i.e.*,

$$\tan \theta_1 = \frac{Y_0 + Y_r}{X_0} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (25)$$

when the forces in the x and y directions are in phase.

In this experiment good minima were obtained so that we can infer that this last condition was satisfied.

The E.M.F.'s induced in the closed loops when their maximum linear dimensions are small compared with the wavelength are—

$$(1) \qquad A\left(\frac{\partial Z}{\partial x} - \frac{\partial X}{\partial z}\right) \qquad \text{in the } xz \text{ loop} \quad . \quad . \quad . \quad . \quad . \quad (26)$$

$$\text{and} \qquad (2) \qquad A\frac{\partial Y}{\partial z} \qquad \text{in the } yz \text{ loop} \quad . \quad . \quad . \quad (27)$$

so that the angle of deviation θ_2 is given by—

$$\tan \theta_2 = \frac{\frac{\partial Y}{\partial z}}{\left(\frac{\partial Z}{\partial x} - \frac{\partial X}{\partial z}\right)} \quad \ldots \quad (28)$$

Now the X and Z forces are in the direct ray transmitted over the surface of the earth.

We can therefore apply Zenneck's analysis of the propagation of plane waves over a semi-conducting medium.

It is not difficult to show that

$$\left(\frac{\partial Z}{\partial x} - \frac{\partial X}{\partial z}\right) = j\nu l\left\{\left(M + \frac{1}{M}\right)\cos\phi - j\left(M - \frac{1}{M}\right)\sin\phi\right\} \quad \ldots \quad (29)$$

where

$$M = \left(\frac{n'}{l}\right) = +\sqrt{\frac{m}{\sqrt{1 + m'^2}}} \quad \ldots$$

(in which the positive square root must be taken)

where

$$m = \frac{\nu K}{\sigma} \quad m' = \frac{\nu K'}{\sigma}, \tan 2\phi = \frac{1}{m'},$$

σ is the conductivity of the ground.

K is the specific inductive capacity of the air.

K' is the specific inductive capacity of the earth.

νl to the accuracy we require is $\frac{2\pi}{\lambda}$ where λ is the wavelength.

Now Y is the component of the electric force in the reflected ray, and we can derive from equations

$$i.e., \left\{\begin{array}{l} \frac{\partial Y}{\partial z} = j\nu n(Y_0 - Y_r)\epsilon^{j\nu(lx - ct)} \text{ (at the surface of the earth)} \\ \frac{\partial Y}{\partial z} = \frac{2\pi j n}{\lambda}(Y_0 - Y_r)\epsilon^{j\nu(lx - ct)} \text{ from (3)} \end{array}\right\} \quad . \quad (30)$$

now

$$\frac{n(Y_0 - Y_r)}{(Y_0 + Y_r)} = \frac{S}{\mu'} + \frac{jS'}{\mu'} \quad \ldots \quad (31)$$

where S and S' have the same significance as in equations (4), (5) and (6), so that

$$\tan \theta_2 = \frac{\frac{2\pi j}{\lambda}\left(\frac{S}{\mu'} + \frac{jS'}{\mu'}\right)(Y_0 + Y_r)}{\frac{2\pi j}{\lambda}(X_0)\left\{\left(M + \frac{1}{M}\right)\cos\phi - j\left(M - \frac{1}{M}\right)\sin\phi\right\}} \quad . \quad (32)$$

and $$\tan \theta_1 = \frac{Y_0 + Y_r}{X_0} \quad \ldots \quad (33)$$

so that $\tan\theta_2 = \dfrac{\left(\dfrac{S'}{\mu_1'} + \dfrac{jS'}{\mu'}\right)}{\left\{\left(M + \dfrac{1}{M}\right)\cos\phi - j\left(M - \dfrac{1}{M}\right)\sin\phi\right\}} \times \tan\theta_1$. (34)

Now in practically every case M is a small quantity, ϕ is nearly 45°, and S approximately equal to S'

so that $$\tan\theta_2 = \frac{\dfrac{S}{\mu'}}{\dfrac{1}{\sqrt{2}M}} \times \tan\theta_1 = \frac{MS\sqrt{2}}{\mu'} \times \tan\theta_1 \quad . \quad . \quad . \quad . \quad (35)$$

where M is a positive quantity and S a negative quantity. θ_2 is therefore of the opposite sign to θ. That is the error when using the horizontal aerial is the opposite sign to that found when using the vertical aerials.

Unfortunately it is not possible to make any accurate numerical calculations, as these involve the electrical constants of the ground in the neighbourhood of the receiving station which have not been measured.

The following calculations based on rough values of similar ground show the approximate magnitude of the deviation to be expected. These do not vary much with the constants.

Take for example :—

$K = 2$. $N = 0{\cdot}133$. $\rho = 10^{15}$. Frequency $= 2 \times 10^5$, where ρ = resistivity in C.G.S. units.

then $S = -2{\cdot}24$, $\dfrac{1}{m} = 4{\cdot}5$, $\tan 2\phi = 4{\cdot}3$

$S' = -2{\cdot}00$, $\dfrac{1}{m} = 9$, $\phi = 38°\ 45'$

$\cos\phi = 0{\cdot}780$ $M = 0{\cdot}328$ $\left(M + \dfrac{1}{M}\right)\cos\phi = 2{\cdot}6$

$\sin\phi = 0{\cdot}626$ $\left(M - \dfrac{1}{M}\right)\sin\phi = -16{\cdot}4$

so that $$\tan\theta_2 = -\tan\theta_1 \cdot \frac{2{\cdot}24 + j\,2{\cdot}00}{2{\cdot}60 + j\,1{\cdot}64}$$

or $$\tan\theta_2 = -0{\cdot}975\epsilon^{-j\phi_1}\tan\theta_1.$$

where $$\phi_1 = 9°\ 25'$$

roughly neglecting the difference in phase $\theta_2 = -\theta_1$ nearly,

or again take $K' = 2$, $\rho = 10^{14}$ n small Frequency $= 2 \times 10^5$

then $S = S' = 6{\cdot}7$, $2\phi = 90°$ very nearly

$$\sin\phi = \cos\phi = \frac{1}{\sqrt{2}}, \quad M = \frac{1}{13{\cdot}4} = 0{\cdot}074,$$

in which case $\tan \theta_2 = -\tan \theta_1 \dfrac{6{\cdot}7 \ + j\,6{\cdot}7}{9{\cdot}55 + j\,9{\cdot}50} = -\dfrac{6{\cdot}7}{9{\cdot}5} \tan \theta_1$

$$= -\,0{\cdot}255$$

$$\theta_2 = 14^\circ\ 20'$$

taking the observed value 21° (= 83 − 62) for θ_1.

In both cases the calculated value of θ_2 is too big. An agreement of the right order is obtained and there is very little room for doubt that the explanation offered is approximately correct.

Reflection and Refraction in a Stratified Medium.

The observed fluctuations in bearings can be accounted for by assuming that the transition layer, where the conductivity increases, is much narrower and more sharply defined at night than in the daytime, and that, in fact, in the latter case the ionisation extends practically down to the ground, while in the former case the lower boundary of the ionised layer is more or less sharply defined. If this is so transmission will be more or less normal in the daytime, and the energy will decrease partly on account of the spreading out of the waves, partly according to the diffraction of waves round the earth and partly on account of absorption in the earth and ionised air.

At night time longer distances will be traversed because the energy is more or less confined to the annular space between two conducting spheres.

This agrees with Dr. Fleming's conclusions on transmission over long distances, and he bases his ideas on a similar theory, *i.e.*, Dr. Eccles' theory of ionic refraction.*

Dr. Eccles has shown that the presence of heavy ions in the air increases the velocity of propagation so that in a medium in which the ionisation increases with the height, the ray leaving the earth will tend to curve downwards and be refracted to the earth again. The curvature depends on the rate at which the velocity of the wave increases with the height, *i.e.*, upon the rate of change of conductivity with the height, if this latter quantity becomes very great this refraction is practically indistinguishable from reflection. The theory in this form is just what is required to explain the fluctuations in bearings at night if it is assumed as well that the transition layer is narrow at night and broad in the daytime.

The theory as given by Eccles is, however, hardly complete as it is not given as a solution of the differential equation of propagation in a medium of varying ionisation. In fact in calculating the path of the ray the effect of absorption is neglected. For this reason I have attempted to solve the particular case in which the conductivity varies in proportion to the height above a given datum.

The work is based on Dr. Eccles' theory of ionic refraction and the same assumptions as regards ionisation are involved. There appears at first sight to be a grave objection to this theory in any form, for it seems to

* J. A. Fleming. *Principles of Electric Wave Telegraphy.* Third edition, p. 842.

involve the possibility of waves being propagated with a velocity greater than that of light. Now this theory is based on Maxwell's equations which are the appropriate expressions of a system in which effect can only be propagated with velocities equal or less than that of light; so that there seems to be a logical contradiction involved.

This contradiction is removed when we observe that according to Eccles' theory the velocity of propagation depends upon the wavelength so that the group velocity and phase velocity are different, and it can be shown that the group velocity which is really the velocity of propagation, is less than that of light.

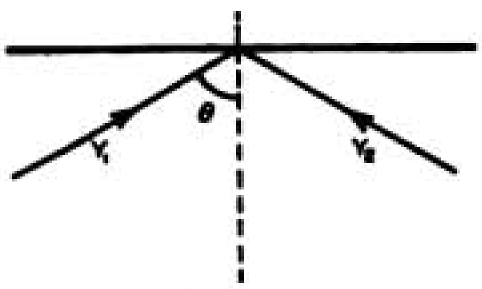


FIG. 11.

I have investigated the case where the conductivity below a certain height is zero, and above that height varies in proportion to any increase in height. It can be shown then that if Y_2/Y_1 is the ratio of the reflected to the incident ray at this surface (Fig. 11), then

$$\frac{Y_2}{Y_1} = \frac{he^2}{8n\,(\nu^2 n^2)\,(m^2 p^2 r f^2)} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (36)$$

where h = the rate of increase of the conductivity with the height.
e = the charge on the ion or electron.
m = the mass of the ion or electron.
$p = 2\pi \times$ frequency of the waves.
f = the frictional force to which an ion or electron is subject when moving with a uniform velocity v, according to which
$v = \frac{Xe}{f}$, where X is the electric force on the charge e.
$\nu = 2\pi/\lambda$, λ is the wavelength,
and $n = \cos\theta$, where θ is the angle the ray makes with the vertical.

We see at once from this solution that when $\frac{Y_2}{Y_1}$ is small the reflected wave Y_2 is proportional to h the rate of increase of the conductivity with the height, *i.e.*, upon the sharpness of the transition, which confirms the statements already made.

Numerical Results.

The quantity

$$\frac{he^2}{8(\nu n)^2 n\sqrt{m^2p^2 + f^2}}$$

which is the ratio of the reflected to incident wave must be of the dimensions of a number. The equations have been expressed in terms of the Heaviside system of units, so that if we use electromagnetic units the quantity

$$\frac{he^2}{8(\nu n)^2 n\sqrt{m^2p^2 + f^2}}$$

must be altered to

$$\frac{he^2c}{8(\nu n)^2 n\sqrt{m^2p^2+f^2}} = h \cdot \frac{e}{m}\left(\frac{ec}{\nu^2 n^3\sqrt{p^2+f^2/m^2}}\right) \quad . \quad . \quad . \quad (37)$$

First Case, where the mass of the ions is so small that p^2m^2 can be neglected in comparison with f^2.
The quantity becomes

$$\frac{he^2c}{8n^3\nu^2 f} = \frac{e^2cN_1}{8n^3\nu^2 f_1} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (38)$$

if N_1 is the number of ions at 1 km height, and f_1 the value of f at this height.

Now the specific conductivity is $\frac{N_1 e^2}{f_1} = \sigma_1$ say . . . . (39)

$$\therefore \frac{\sigma_1 c}{8n^3\nu^2 \times 10^5} = \text{ratio of reflected to incident wave} \quad . \quad . \quad . \quad . \quad (40)$$

If we assume that this ratio has a value of 10 per cent. say, then we shall have an equation for σ_1

$$\sigma_1 = \frac{1}{10} \cdot \frac{8n^3\nu^2 \times 10^5}{c} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (41)$$

Take $\lambda = 600$ metres say—

(1) Take $n = 0{\cdot}1$

then
$$\sigma_1 = \frac{8 \times 10^{-3}\left(\frac{2\pi}{600}\right)^2 \times 10^{-8} \times 10^5}{10 \times 3 \times 10^{10}} \quad . \quad . \quad . \quad . \quad . \quad . \quad (42)$$

which is of the order of $\frac{10^{-16}}{3}$.

(2) Take $n = 0{\cdot}5$

σ_1 is of the order $\frac{1}{6} \times 10^{-13}$ absolute units

which is of the same order as the conductivity of dry earth and seems a quite reasonable value to assume.

Schuster has shown that it is necessary to assume a mean conductivity of this order to account for the diurnal changes of the magnetic elements in his theory.

Accuracy of this Estimation.

The accuracy of the asymptotic solution we have used is of the order of the last term used in the series.

This term is

$$T = \left|\frac{1 \times 5}{4^2 \times 3} \cdot \times \frac{\phi}{(z_1)^{\frac{3}{2}}}\right|_{z=0} = \left|\frac{5}{48} \cdot \frac{\phi}{r^{\frac{3}{2}}}\right| \quad . \quad . \quad . \quad . \quad . \quad (43)$$

now
$$r = \nu^2(1 - l^2) = \nu^2 n^2$$

so that
$$T = \left| \frac{5}{48} \cdot \frac{\phi}{\nu^3 n^3} \right| = 0{\cdot}104 \frac{\phi}{\nu^3 n^3} \quad . \quad . \quad . \quad . \quad . \quad . \quad (44)$$

but $\frac{Y_2}{Y_1} = 0{\cdot}125 \frac{\phi}{\nu^3 n^3}$ so that the accuracy of estimation of Y_2/Y_1 is practically equal to its magnitude, in the case we have assumed 10 per cent.

Second Case.—mp and f comparable.

The quantity $\frac{N_1 e^2}{f_1}$ is still the mean conductivity for steady electric forces, but instead of $\frac{he^2 c}{8\nu^2 n^3 f}$

we have
$$\frac{he^2 c}{8\nu^2 n^3 f\,(1 + m^2 p^2/\alpha^2)^{\frac{1}{2}}} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (45)$$

i.e.,
$$\frac{\sigma_1 c}{\nu^2 n^3 \times 10^5} \frac{1}{(1 + \alpha^2)^{\frac{1}{2}}}, \text{ say}$$

and the values of σ_1 before obtained have to be multiplied by the factor $(1 + \alpha^2)^{\frac{1}{2}}$ which is large compared with unity when mp is large compared with f.

In the calculation of σ we have assumed that f is large compared with mp. We can get an estimate of the lower limit of the ratio $\frac{f}{mp}$ by assuming the ions or electrons have their maximum mobility at the specified pressure. Kaye and Laby give the maximum mobility of the negative ion produced by X-rays as 1·7 (cm) × (sec.)$^{-1}$ (volts)$^{-1}$ at normal pressures and temperatures. The mobility at low pressures should increase inversely as the pressure

$$K_p = 1{\cdot}7 \times \frac{P_0}{P} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (46)$$

$$K_{p(\text{abs.})} = 1{\cdot}7 \, . \, \frac{P_0}{P} \times 10^{-8}$$

now under a steady electric force

$$fv = Xe \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (47)$$

or
$$f = \frac{Xe}{v} = \frac{10^8}{1{\cdot}7 \frac{P_0}{P}} \, . \, e$$

and
$$\frac{f}{mp} = \frac{10^8}{1{\cdot}7 \, . \, p} \frac{e}{m} \cdot \frac{P}{P_0} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (48)$$

taking
$$p = 3 \times 10^6$$

$$\frac{f}{mp} = \frac{3{\cdot}4 \times 10^8 P}{P_0} \text{ about} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (49)$$

and this is a large quantity so long as $\frac{P}{P_0}$ is not less than $\frac{1}{10^6}$ say.

At the height of about 100 km $\frac{P}{P_0}$ is of the order of 5×10^5, and for hydrogen and the lighter gases it is even greater than this, so that the condition $\frac{P}{P_0} \nless 10^{-6}$ seems to be satisfied under all normal conditions at this height. If the pressure P were so small that the interval between encounters of electrons and molecules was large compared with the period of the waves then the absorption of energy, of which f is the measure, is due to the acceleration of the electrons produced by the electric forces in the wave.

Summary

If the experiments in this paper are considered to be valid then the existence of a ray reflected at night time from some upper conducting layer of the atmosphere may be considered to be beyond doubt, and the fact that this ray is responsible for part of the errors in night bearings may also be taken as proved. But a doubt still exists if this is the only way in which errors are produced, and it is still uncertain whether the errors are due to a ray reflected in a purely vertical plane from a perfectly horizontal conducting layer, or by reflection from a partially tilted layer. Probably both these causes of error exist.

Experiments as described on p. 239 should determine this point.

The manner in which the ray is reflected is suggested in the later, more speculative, part of the paper and it seems that a possible explanation is offered, and that the numerical values of the conductivity and rate of increase of conductivity with height required by the theory are not impossible.

Many points in connection with this subject have not been touched upon for instance the apparent systematic swinging of bearings at sunset, and the variation of bearings taken on radiophare stations as the transmitter rotates, as observed by Captain Tremellen, and his results on the sunset variations of the strength of signals from Clifden all of which might probably be explained on the reflection theory, but the satisfactory result remains that a reasonable explanation of night effects has been offered and confirmed by experimental results.

Some Acoustical Effects in Wireless.—A paper with this title was read by Capt. J. Robinson, M.Sc., Ph.D., at a meeting of the Wireless Society of London on April 4th, 1921. The author pointed out the importance of acoustical effects in wireless, and then discussed the heterodyne effect and the lag of the ear as a function of the pitch of the note. When transmission is rapid, dots may be missed if the heterodyne beat note is made too high. The variation of the oscillation frequency of a valve with the potential of the anode battery was dealt with, as well as the production of notes by a high-frequency oscillating valve making use of a grid leak and condenser, and the factors governing the pitch of this note were discussed. The application of this arrangement (termed by Major Prince a "squegger") to a receiver in which the pitch of the note heard in the telephones is a function of the strength of the signal, was also described.

A New Radiomegaphone.

Considerable interest has been aroused recently in the claims made for a new receiving apparatus that has been installed in the electrical engineering laboratories of the College of the City of New York of which Dr. G. N. Goldsmith, the secretary of the Institute of Radio Engineers, is director. The development of the receiver to its present pitch of perfection has been the result of many years of research work. It involves the use of no essentially new discovery but the good results obtained are due to gradual development and improvement of the component parts of the amplifier. Ten three-

electrode valves are employed in conjunction with a loud speaking telephone. The wavelength tuning range of the set includes 600 metres as well as the long wavelengths used for transatlantic signalling, and it is claimed that the signals obtained from Nauen (Germany) are almost uncomfortably loud all over the laboratory. Claims made for the instrument are great selectivity in tuning, and distortionless amplification. From the attached illustration it may be noted that the last valves of the set are of a much larger size to permit of the handling of more energy for operating the loud speaking telephone.

Nauen and Togoland: A Tragedy of Radio-Telegraphic Development.

By Dr. R. ROSCHER.

(Concluded from page 75 February issue.)

THE CONSTRUCTION OF THE LARGE WIRELESS STATION KAMINA (TOGO). THE PERMISSION TO CONSTRUCT LARGE WIRELESS STATIONS IN THE GERMAN PROTECTORATES IN AFRICA.

While it was still an open question whether the contemplated large wireless station uniting the African colonies with the mother country should be built in Togo or Kamerun, there was much to be said in favour of Kamerun. It was the larger and more important of the two Protectorates, and the defence of the station could there be assured, whilst this was not possible in the narrow Protectorate of Togo, enclosed by French and English territory, and insecure against possible surprises, owing to the small military forces at its disposal. On the other hand, difficulties of transporting apparatus and machines, difficulties of telegraphic connection with the coast, stood in the way of finding a suitable location in Kamerun. After the favourable results of the preliminary tests in Togo it was therefore resolved not to wait for the results of further experiments, but to construct at once a fully equipped large wireless station in Togo in order to establish connection as soon as possible. Kamerun would in any case, through the coast wireless station Duala, be joined up with the colonial wireless network *via* the Togo wireless station.

Although the capital required, and consequently the economic risk, is considerably less for wireless telegraphy plant than for cables, it was nevertheless decided not to charge the construction of either the large wireless stations or the coast stations in Africa directly to the imperial budget. The problem to be solved in such constructions required a large amount of special experience. In view of the peculiar nature of wireless telegraphy, unexpected difficulties in the technical details of construction or operation might occur, difficulties which a private undertaking, free to move in any direction and having at its disposal a staff of trained engineers, could more easily overcome than the Imperial Government, which did not possess any body of men trained in the building and operation of large wireless telegraphy establishments situated in oversea territories. The private concern coming naturally first in question was the Telefunken Company. The chief considerations in its favour were (1) that it had established itself firmly in all parts of the world, (2) that it had already built a large number of wireless stations abroad, and, in particular, the establishments in the German Protectorates, (3) that in doing so, as well as in carrying out the range tests and the preliminary experiments for bridging the distance between Germany and Central Africa, it had gathered valuable experience which would be immediately useful for the present purpose, (4) that hitherto no other company had either guaranteed or effected such a connection.

In view of these considerations and of the successful issue of the preliminary tests, the Company on June 12th, 1913, was granted permission to construct one direct radio-telegraphic connection between Germany and Togo and one between Togo and German South West Africa and to work them for a period of twenty years reckoned from the day on which the operation of the connection should definitely begin. The permission was granted subject to the following conditions:—

The Company guarantees, at its own cost—

(*a*) To erect at Atakpame in Kamina (Togo) and to operate for twenty years a wireless station capable of communicating with the station at Nauen as well as with a station in German South West Africa and a projected station in German East Africa.

(*b*) To enlarge and improve its station at Nauen so that mutual communication should be possible between that station and the station in Togo.

(*c*) To erect and operate for a period of twenty years a station at Windhoek (German South West Africa) capable of communicating with the establishment in Togo and with the station projected for East Africa.

At the demand of the Imperial Government, the wireless stations named in (*a*), (*b*) and (*c*) were to communicate with other German and foreign stations as far as communication was possible. In a general way, daily communication to and fro between the stations in Togo and Nauen for four hours was to be possible with a minimum speed of seventy-five letters per minute. If on individual days, in consequence of atmospheric disturbances in Togo, this minimum could not be attained, it was stipulated that within any five consecutive days at least 1,200 paid words of ten letters should be transmitted in each direction. For the connection Togo—South West Africa an assured daily communication of at least four hours with a minimum speed of seventy-five letters should be practicable. If, in consequence of atmospheric disturbances, communication were interrupted for more protracted periods, the imperial subsidy was to be reduced. This subsidy was to be 592,000 marks for the Togo station, and 454,000 marks for the station in South West Africa; it was to take effect from the day on which the operation of the stations definitely commenced and should continue for a period of twenty years. The definitive operation of the Togo—Nauen connection should begin when, during the test operations, the prescribed minimum had been reached for at least thirty days. The operation of the Togo—South West Africa connection should definitively begin when, on eight consecutive days, 400 words of ten letters could be transmitted daily with a speed of seventy-five letters per minute. The Imperial Government reserved to itself the right of purchasing at any time the wireless stations in Togo and South West Africa. The Imperial Government was to pay to the W.T.C. a yearly sum of 111,500 marks for placing its Nauen station at the disposal of the Government for communication between Germany and Togo, and for operating this station with its own employees. There was conceded to the Imperial Government the option of purchasing the station at Nauen, which station might be acquired at any time. The Imperial Government was to receive for the use of its wires the usual fees paid for telegrams proceeding from or going to Germany and her interior, or the German Protectorates and their interior, when these telegrams had to traverse the wireless telegraphic routes for which this present permission was granted ; it was also to receive 75 per cent. of the fees payable for the transmission of telegrams over these wireless routes. The Imperial Government was empowered at any time temporarily to operate the station by its own officials. The operation of these wireless routes should be regulated by the International Telegraph Convention, the International Wireless Telegraph Convention, the various agreements for applying these Conventions and the special imperial decrees for the radio-telegraphic service. The determination of fees, the conclusion of agreements with other telegraph administrations concerning the transmission of telegrams, as well as the conclusion of all agreements with other governments were subject to the

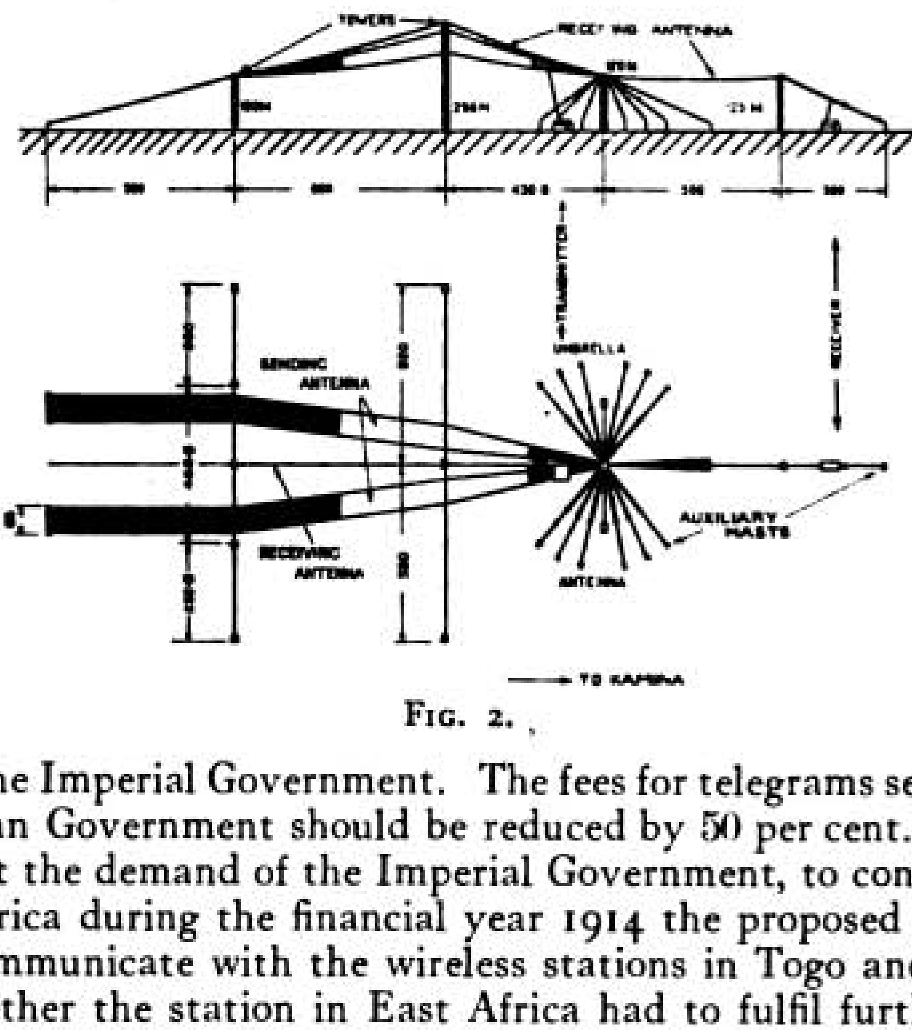


FIG. 2.

approval of the Imperial Government. The fees for telegrams sent or received by the German Government should be reduced by 50 per cent. The W.T.C. was bound, at the demand of the Imperial Government, to construct in German East Africa during the financial year 1914 the proposed large wireless station to communicate with the wireless stations in Togo and South West Africa. Whether the station in East Africa had to fulfil further tasks was reserved for the decision of the Imperial Government. A subsidy was also to be paid to the Company for the construction and operation of this latter station. The Imperial Government might cause experiments to be undertaken by the W.T.C. in order to ascertain whether direct communication was possible between Nauen on the one hand and the large wireless stations in South West Africa and East Africa on the other, or by what means such communication could be attained. Authorisation was given to the Imperial Post Office to acquaint itself at any time with the circumstances of the undertaking for which the present authorisation was granted.

It was laid down by a special agreement that the W.T.C. should possess no monopoly of radio-telegraphic transmission of telegrams between Germany and the African Protectorates or between the latter themselves. In respect of the experimental operation of the stations, it was agreed that this was to show whether the individual parts, separately as well as collectively, were able to meet all requirements even when working at high pressure, what wavelengths were best suited for operation by day and by night, and how the hours for operation could best be chosen.

The plant at Nauen had to be increased as follows for the communication with Africa. A quenched spark transmitter of 100 kW antenna power was installed. A main tower 252 m in height, and five towers each 120 m in height, were to support the antenna. The transmitting antenna was to consist of twenty stranded bronze wires 800 m long and 4 mm in diameter. The receiving antenna of two stranded bronze wires 1,700 m long and 9 mm in diameter. The arrangement can be seen from Fig. 2.

THE DESCRIPTION OF THE LARGE WIRELESS STATION AT KAMINA.

The large wireless station in Togo, for which the situation decided upon was that used for the experiments, at Otakpame in Kamina, was arranged for an antenna power of about 100 kW; for the connection between this station and the coast establishment in Lome, supplementary apparatus of 2·5 kW antenna power was contemplated. Three iron frame masts, each 75 m in height, and six, each 120 m in height served to support the antennæ; of the latter masts, four were surmounted by extensions 7 m in height for the receiving antenna. The transmitting antenna consisted of twenty stranded bronze wires (5 mm in diameter) 600 m in length, the receiving antenna, of a brass rope (12 mm) 3,350 m in length, the earthing system of thirty copper plates, the insulated counter capacity of twenty copper wires (2·5 mm) and about 1,600 m in length. Besides that, a small transmitting-receiving antenna was provided for the supplementary wireless station.

To the power station belonged :—

(*a*) The boiler house with three tube boilers (one of them as reserve) arranged for wood firing. The wood was to be obtained from an afforestation situated in the Protectorate. Even during the war, firing was done with wood obtained in the neighbourhood. This mode of working proved quite satisfactory. The boiler house was equipped with all essential accessories, *e.g.*, water and steam gauge, water purifier, ring steam main, economiser and forced draught. For the cooling of the condensed steam there was a huge cooling apparatus 30 m high.

(*b*) The turbine and steam engine establishment consisting of two steam turbines of 500 H.P. and two vertical steam engines of 120 H.P. (one of each as reserve; in fact all parts of the power station were duplicated).

(*c*) The main power plant with the following parts :—

(α) Two alternating-current generators, each of about 350 kW (one of them as reserve), directly coupled with a steam turbine.

(β) Two continuous current machines each of 75 kW and 220—250 volts (one as reserve) directly coupled each with one of the 120 H.P.

steam engines, for exciting the alternating current generator, charging the storage battery, driving the air pumps.

(γ) One strong battery with 131 cells, 259 ampere hours at the one hour discharge rate.

(δ) One Booster set consisting of continuous current motor and supplementary dynamo of about 15 kW, 20—30 volts.

(ε) One continuous current—alternating current transformer of 10 kW (for the auxiliary transmitter).

The transmitting plant consisted of the main transmitter (100 kW oscillating power in the antenna for waves of 3,500, 4,200, 5,500, 7,500, and 9,500 m) and the auxiliary transmitter. The receiving equipment consisted of three telephonic receiver sets with a continuous wave range of 200 to 14,000 m for the large wireless plant, and 300 to 2,500 m for the supplementary one.

The buildings of the wireless station included the transmitting house, consisting of boiler house, engine house, high frequency room, battery room, firewood sheds, workshop, storeroom, the dwelling house for the manager, the receiving house, a dwelling house for the telegraphists, as well as one for the machinists.

A light railway more than 5 km in length was built connecting the village Agbonu, a station on the Togo hinterland railway, with the wireless station, in order to convey the iron parts for the supports of the antennæ, the machines, etc. At the railway station of Agbonu stood a crane spanning the tracks of the Togo railway and the light railway and permitting the direct transference of goods from the one to the other. The light railway led through the bush to Kamina alongside the road constructed by the Company. A branch line connected the wireless station with the place whence was obtained the sand serving for the manufacture of cement and tiles, which were always used for the permanent houses. On the building plot were three deep wells from which water was raised by means of electric centrifugal pumps into a reservoir 10 m high. From the reservoir the water flowed to the various points where it was required, the boiler house, the dwelling house, the brick field, the washhouses, etc. The brick field was near the reservoir.

The enormous plot, covering an area of four square km, and traversed by a light railway of 4 km in length and by roads 8 km long, had been conceded free of charge by the administration of the Protectorate. Difficulties of various kinds had prevented the work of construction from running smoothly: a fire broke out, and building material was lost in the surf at Lome in an attempt to extinguish it, etc. A trial operation of the station was to precede its definite opening. This trial was begun on June 20th, 1914, but was discontinued owing to the outbreak of war.

The Large Wireless Station Kamina during the War. Its Achievements.

The war, which put a stop to the creation of a German network of wireless stations, afforded an opportunity of showing whether the Kamina station was capable of standing so severe a test. That it did in the fullest measure.

Shortly after England had declared war, and after a proposal to remain neutral, made by the Governor of the Protectorate Togo, had been rejected by the Governor of the English Gold Coast Colony, two English messengers arrived to negotiate with the Governor the surrender of Lome and a part of the Protectorate. The Governor of Togo found himself obliged to give up Lome and ordered that the place should be surrendered to the English on the following day, whilst those Europeans who were capable of military service should proceed with the police force under his command to Kamina, in order to defend the wireless station there; such being the instructions of the Imperial Colonial Office. On the evacuation of Lome and the hinterland, during the night of August 6th and 7th, 1914, the coast wireless station at Lome was destroyed to such an extent that its restoration was made exceedingly difficult, if not impossible. The tower of the station was overthrown.

The large wireless station Kamina rendered extremely valuable service, although the preliminary tests were not yet ended, and although the establishment had not yet been taken over and did not yet possess all the equipment destined for it. At first the station was kept ready at any time to receive from and transmit to the counter establishment at Nauen. Later on, such hours were fixed for receiving from and transmitting to the stations at Nauen, Windhoek, Duala, as were found most favourable for the respective stations. In communicating with Windhoek and Nauen, the wavelength used by day was 6,000 m and by night 4,500 m. Duala transmitted by day with a wavelength of 2,500 m and by night, 1,600 m, Kamina always with the 4,300 m wave. Especially important was the connection Kamina-Duala after the destruction of the coast wireless station at Lome.

The warning issued to the merchant ships lying within the range of Kamina, and the summons to put into neutral harbours produced good results; it is well known that but few ships fell into the enemy's hands. Statistics drawn up after an inquiry made by the Scientific Committee of the Prussian Ministry for War show that the warning signals sent by German wireless stations saved the country 800,000 tons of shipping. The Hamburg-America line stated that forty-seven steamers of 287,237 gross tonnage had been saved by wireless telegraphy and estimates the value of these steamers at 93·3 million marks. The overseas German stations, in particular the large establishments at Kamina and Windhoek, contributed largely to this work of rescue.

What imparted greatest value to the Kamina wireless station was the fact that after the German cable had been cut, the mother country still possessed independent means of maintaining the important connection with her West African colonies. Even telegrams from Western Europe to Berlin which had failed to reach their destination owing to the cutting of European connections, were sent by the circuitous route *via* Spain-Teneriffe-Monrovia-Lome (by the cable of the German South American Telegraph Company) and thence by radiogram *viâ* Kamina to Nauen. By agreement with the cable station Pernambuco, a considerable portion of the communication it normally carried on between South America and Germany was deflected *viâ* Lome—

Kamina; this intercourse would otherwise have been either impossible or subject to very great delay, after the cutting of the German cable on August 5th, 1914; since the foreign routes which might be used as substitutes were so fully occupied. It was only ascertained later that a unidirectional connection Kamina—German East Africa had been achieved. News from Kamina, including important official telegrams, was received by an establishment constructed out of equipment taken from wireless stations on board ships and from the demolished station at Dar es Salem. For the sake of additional security Windhoek was likewise requested to transmit the telegrams for German East Africa. From the military and political point of view as well, a constant connection with Berlin and the transmission of official news to Duala and Windhoek was a great advantage. The direction Kamina—Duala worked well, and thus the fears previously mentioned proved groundless. Also all telegrams from Duala to Kamina could be received and forwarded to their destination, but often with considerable delays, and at times the signals were very weak or failed to arrive altogether. The cause of this lay in the heavy load on the sole storage battery (there was no reserve battery) in consequence of the very frequent war communication with Fernando Po, the steamer *Kamerun* lying at the entrance to the harbour of Duala, the coast wireless station Lome and the large wireless station Kamina. When messages were sent with the machine, they were distinctly received in Kamina so long as the motor in Duala was running evenly; but so soon as it began to run unevenly, Kamina did not receive them. Transmission by means of the machine had the further disadvantage that in the meantime the battery could not be charged, whilst the noise of the machine made very difficult or even completely prevented the receiving of telegrams in the receiving room near by. In spite of all these difficulties, from August 1st to August 24th, 1914, 248 telegrams were transmitted for Kamina and these were all received and deciphered. The disturbances wilfully created by hostile wireless stations, by the Eiffel Tower for instance, did not seriously hamper the receiving of the telegrams. The wireless communication of the Eiffel Tower with French land stations could often be followed. During the very limited periods of leisure, attempts were made to disorganise hostile communications, for instance those between the Eiffel Tower and the wireless establishments on the English battleships, and those between the enemy's coast establishments.

The traffic to be coped with by the large Kamina wireless station was large, considering that generally telegrams in cipher were involved. During August 152 telegrams of 4,511 words were transmitted from Nauen to Kamina in 2,938 working minutes and in Nauen seventy-seven telegrams, of 1,828 words were received.

The hours most suitable for the receiving of telegrams were ascertained to be 1 a.m.—4.30 a.m. and 8 a.m.—1 p.m. The present writer was repeatedly one of the listeners and can testify to the clearness with which messages were received. Apart from a small local disturbance, caused by the breaking of a connection between the amplifier and the battery, no other disturbances occurred. The atmospheric influences were at times so strong during the hours just described as the most suitable for working, that operations were difficult.

At the large wireless station of Nauen, which on the outbreak of war was taken over by the Government and occupied by the military authorities, the antenna arrangement then consisted of one tower 250 m high, three frame towers of iron and one Rendahl mast, each 120 m in height. Between the towers was suspended an antenna, consisting of twenty wires, and directed towards Togo (Kamina); its natural wavelength was 4,000 m and its capacity 16,000 cm. As transmitting apparatus there were a quenched spark transmitter of 80 kW and a high frequency generator of about 100 kW. The frequency of the generator was 8,000 cycles, the spark transmitter worked with waves of 4,800, 6,500, 7,500, and 9,400, and the high frequency generator with waves of 9,400 and 4,700 m by means of frequency doublers.

THE DEFENCE OF THE LARGE WIRELESS STATION.

On the arrival of the field troops of the Togo Protectorate at the wireless station Kamina, it became urgently necessary to link together telegraphically important points of the defence zone, and to connect them with the probable main routes of the enemy's advance. A field telegraph division was formed for this purpose. Serious difficulties confronted the construction and operation of a sufficiently extensive and ramified field telegraph network. Trained men were lacking; the only ones available were the postal officials of the Protectorate. Moreover, apparatus and wire were strictly limited. Fortunately, when Lome was evacuated, all the stocks of telegraphic material which could be seized and transported, had been taken; this was supplemented by the post office stocks accessible from Kamina, especially those of the neighbouring Atakpame.

Essential to success was the training of suitable staffs for the construction and operation of the network. Europeans, whose profession or special qualities rendered them suitable for the task, were thoroughly trained as operators and as foremen for the laying of field lines, and coloured men were trained to do the more menial work; among the latter were the strong and industrious Kabure men, brought from the northern hinterland to Kamina by the Governor as labourers.

The most important strategical centre was located at Kamina, constituting the headquarters of the system. It was connected with the receiving house of the large wireless station by utilising a pair of conductors of a cable previously laid for lighting purposes. The rest of the lines were made of the excellent bronze wire, 3 mm diameter, belonging to the imperial telegraph service; this wire was attached to natural supports (trees, etc., or rude poles), but in many places it had to lie on the ground. As far as practicable, the existing network of the postal service of the railway was used along with the improvised system. The chief technical centre was set up at the railway station of Agbonu, the terminus of the hinterland railway from Lome, by utilising an exchange cabinet taken from the equipment of the postal service. Generally earth return was employed, metallic circuits only being used where cores were available. Intermediate stations were connected in parallel. Considerable stretches had in some cases to be linked up. A postal service with several deliveries daily was established between Kamina and Atakpame, where the European soldiers were quartered.

The strategical situation soon necessitated an extension of the network towards the south-west, from which direction the French might be expected to approach from Dahomey. The field telegraph station Njamassilä served as point of support for scouting operations in the direction of Dahomey, and communicated by means of a cyclist corps with the more advanced scout troops.

Two principles had to be kept steadily in view during the defence: (1) to hold and operate as long as possible the large wireless station, and (2) when it had to be surrendered, in no case to let it fall into the enemy's hands in working condition—such were the repeated injunctions of the Colonial Office.

Military considerations determined the line of conduct to be adopted in respect of the former of these two principles. The narrow Protectorate of Togo, enclosed between English and French possessions, disposed of very scanty forces (a police troop). For the defence there were available 150 Europeans (many of them not soldiers)—these, in so far as they were not used for other purposes, were formed into a European company, and the police troop of the Protectorate, about 400 coloured men, the majority of whom were reservists or recruits. It was impossible to man a line of defence round the entire station, including the portion of the aerial absolutely essential for the working of the station. That would have required 6,000 men. The Vice-Governor thought to make the power house, the workmen's house and the receiving house the last points of defence, and to proceed to the work of destruction when these buildings became untenable. Thus the destruction would be deferred as long as possible, but it was very doubtful if it could then be made complete. Besides, it would be impossible to continue the working of the station once the enemy had occupied the antenna region outside these buildings, because he would naturally at once have destroyed the antenna.

After consultation with the senior officers and the representatives of the Wireless Telegraph Company, it was decided that the destruction of the power house and the receiving house would not suffice to render the wireless station useless; the towers must not be allowed to remain standing. Otherwise, by means of transmitter appliances obtained from battleships or elsewhere, the enemy might either disturb or intercept the communications of other German wireless stations (Duala, German merchant vessels and warships, perhaps even the Nauen—Windhoek traffic) and might obtain valuable additions to his own means of sending news between Kamina and English and French wireless stations in West Africa on the one hand, and England and France on the other. From four to five hours were considered necessary to destroy the station and throw down the towers. When to begin the destruction must be determined by the military situation, *i.e.*, it had to be begun when the capture of the wireless station might be expected within four or five hours.

The Imperial Colonial Office was asked for instructions. Its answer of August 16th ran "Measures left to discretion of men on the spot. Important station must in no case fall intact into enemy hands."

After this, the defence methods hitherto adopted had to be changed. Trench digging was discontinued. The existing network of field telegraph stations protected by sentries or larger forces was extended, so that the Governor, by means of continuous communications received from them at Kamina, was kept exactly informed of every change in the situation in the whole of the defence zone.

This change necessitated still greater exertions on the part of the field telegraph division; fresh stations had to be added to the network, *e.g.*, south of Kamina, on the Chra and in Amuno. For lack of time, bare copper wire had frequently to be laid on the ground for long stretches. As was to be expected, the extension of the line eastwards, towards Tscheti, was extraordinarily difficult. The difficulties began on the way to Awagome, a resting place on the road from Atakpame to Sakode. The Kabure men used as wire carriers, weary of their burden, had thrown away most of the coils of wire and fled into the bush. With great pains a sufficient quantity of wire was sent to Awagome, the starting point of the new line, to begin the work of construction. This work was attended with all the difficulties such bush terrain can present. Apart from two white and one coloured post messenger, told off to run the station, only Kabure men were available, and these, besides being totally ignorant, had lost their morale through the uncertainties of the campaign and displayed but little of the willingness and zeal with which they are usually credited. The terrain was as unfavourable for the construction of the line as it possibly could be. Where grass, high as a mounted rider, did not impede the advance, fallen trees did, or stout tree roots running across the path, or large stones and pools of water, or unbridged streams swollen by rains; it was often impossible to proceed before the obstacles had been removed or bridged. Such hardships added to the lack of food and an incessant tropical downpour made the men so disinclined to work that only extreme rigour could induce them to hold out. If the construction were not completed before nightfall, it would be impossible to count on a sufficient number of men for the next day.

When night fell, the intended terminus had not been reached by several kilometres. A trial of the line was made at a temporary station in the forest, and with great delight it was found possible to speak with Kamina, in spite of the loss of current along the bare wire laid in wet grass, although "ringing up" was not practicable. It was arranged that this new station should be switched on to the line and announce itself ready to receive news at fixed intervals. The next day the line was lengthened as far as the village Agbakovhe. From Agbakovhe cyclists communicated with the post stationed on the river Monu, whence scouts reconnoitred further in the direction of the enemy. The new station rendered especially valuable service, as the French were advancing from this quarter.

The field telegraph system worked satisfactorily throughout the campaign. Few interruptions occurred and these were quickly remedied. This was due to the excellence of the material employed and the zeal of the employees, whose devotion in their hard task was most praiseworthy, in spite of insufficient food supplies due to bad roads and the lack of reliable carriers.

Special care had to be exercised in the working of the system in order to prevent coloured men from communicating damaging news to the enemy. It was arranged to speak only German on the field lines, to man continuously the various stations with at least one European and to carry on no private conversations.

The method of defence adopted proved itself excellent. A systematic scouting service was arranged and the results speedily announced to the commander, thus enabling him to dispose of his forces to best advantage and send his orders immediately to the remotest points. The capitulation of the large wireless station was in the end inevitable in view of our inferiority in men and munitions, but it was delayed until August 27th, 1914, after a battle had been fought on the Chra (47 km south) inflicting heavy losses on the enemy and retarding his advance.

THE DESTRUCTION OF THE STATION.

After the commander had given orders to destroy the large wireless station, the work of destruction was carried out as follows: On a signal being given by steam sirens, the members of the thoroughly drilled "blasting division" (employees of the Wireless Telegraph Company and other Europeans and natives) took up their positions and the "evacuation police" completely evacuated the endangered terrain; then the director of the operations, standing near the engineers' house from which he had an unimpeded view in all directions, gave the order by telephone to the receiving house (northern stay mast of the aerial) and by cyclists to the post by the southern stay mast of the aerial: (1) to let down the receiving antenna. As soon as the antenna had fallen it was to be cut by men detailed for that purpose. Simultaneously by telephone order was given (2) to destroy the receiving room and (3) to destroy the power house. Apparatus, machines, auxiliary appliances were for the most part blown up or broken in pieces, written documents, drawings etc., were burnt. Then the order was given (4) to destroy the transmitting antenna. The antenna was loosened at several points and, after it had fallen, cut through in different places. The men then proceeded (5) to pull down the towers by loosening the back-stays attached to the stay-wire foundations. The towers fell with a loud crash full length in the desired direction, some of them being telescoped. The frame was completely bent. It was told how the crash of the falling towers could be heard far away in the silent night.

Although the station had to be destroyed during the night and under a cloudy sky, the work was carried out without untoward incidents. Fortunately there were no discharges of atmospheric electricity, which might have defied all the care taken to prevent harm to the men involved. An enemy surprise had to be reckoned with—English officers told the present writer that scouting parties had been in the immediate neighbourhood shortly before the towers were pulled down—and consequently the destruction had to be accelerated as much as possible. It was accomplished in four and a half hours, two and a half hours longer than had been anticipated owing to the difficulties caused by darkness and the rusting of the back-stay screws. It has been stated by our enemies (No. 81 of the *Wireless World*, of 1919) that we ought to have contented ourselves with putting the large wireless station out of action, but that we ought not to have destroyed unessential parts. In reply it must be emphasised that the destruction was an inevitable consequence of the war. Such an important instrument of communication could not be allowed to fall into the hands of the enemy who could have used it for his own purposes and inflicted great harm with it on his antagonist. In particular, our enemies would have been able to disturb the communication between German warships and especially that between the wireless stations Duala and Windhoek and between Windhoek and Nauen. If, on the other hand, only important parts had been destroyed, those parts which had remained intact might have been made workable again by means of supplementary parts or have been utilised for warlike purposes elsewhere. In any case they would have increased the armaments of the enemy. As, moreover, it was the duty of the defender, to keep the station in working order as long as possible, the destruction of the establishment which with its nine lofty towers occupied an extensive terrain had to proceed with the utmost dispatch, otherwise it would have been incomplete on the arrival of the enemy whom the meagre defensive troops might indeed delay, but could not repulse. For this reason, the destroyers were unable leisurely to select those parts which they deemed sufficient to prevent the station being put again in working order in a short time. A further principle guiding the work of destruction was that valuable technical secrets should not get into enemy hands, especially seeing that neither English nor French had hitherto succeeded in establishing reliable wireless communication over such distances in the tropics.

Had the large wireless station destined to join Germany with her African colonies been erected in the interior of Kamerun, it is highly probable that it could have held out longer than the Kamina station, so unfavourably situated in case of war. Presumably the Kamerun campaign would from the outset have been carried on more energetically and troops would have been taken for it from the Togo enterprise, nevertheless it seems certain that the capture of the station would have been considerably later. Disregarding, therefore, the above-mentioned important reasons for selecting Togo and bearing in mind only the course of the military operations, one is compelled to admit that Kamerun would have been preferable as a situation for the wireless establishment.

Thus did the first large wireless station to be erected in the tropics fall a sacrifice to Bellona. Though not yet definitely taken over, Kamina satisfied the enormous demands made upon it by the circumstances of the war. It was fortunate that this important station had been completed just before the outbreak of hostilities and that, after the destruction of cable connections, communication with the motherland was still possible. Although an inauspicious fate cut short the time of its active life, Kamina will ever remain an important landmark in the development of world traffic.

Notes.

Personal.

Frederick A. Kolster, who is well known as the inventor of a direct reading decremeter, and for other useful contributions to the radio art, has resigned from the Bureau of Standards, Washington, D.C., to take up an appointment with the Federal Telegraph Company, California. **[2520]**

M. Blondin, the director of the *Revue Générale de l'Électricité*, has been nominated a Chevalier of the Legion of Honour. **[2467]**

Mr. Frederick G. Simpson, electrical engineer, formerly chief engineer and general manager of Kilbourne and Clark Manufacturing Company, and the Ship Owners' Radio Service, Inc., has established offices at the L. C. Smith Building, Seattle, Washington, for the design and construction of electric plants of all descriptions. **[2541]**

Dr. Leonard F. Fuller, the designer of the American type high and low power Poulsen arc transmitters, has entered the service of the Wireless Improvement Company, who have their works and offices in Jersey City, New Jersey, U.S.A.

Dr. Fuller will have charge of the design, construction, development and research work in connection with all arc transmitters to be manufactured by this company in the future.

Prior to joining the Wireless Improvement Company, Dr. Fuller's work included the design of such arcs as the 1,000-kW units installed in the Bordeaux (France) station, which are the largest in the world, as well as of practically all of the high and low power stations of the American Navy Department. **[2569]**

Commercial.

PERUVIAN POSTS AND TELEGRAPHS.—By agreement with the Peruvian Government, Marconi's Wireless Telegraph Co., Ltd., will on May 1st take over and operate for a period of twenty-five years the whole of the postal, telegraphic and wireless services of Peru, receiving as remuneration 5 per cent. of the gross receipts of the services and 50 per cent. of the annual profits. Sir William Slingo, late Engineer-in-Chief of the British Post Office, has accepted the position of Chief of the Peruvian Postal and Telegraphic Department. Of the approximately 9,000 miles of telegraphic communication in Peru some exist at a height of 16,000 feet, notably where crossings of the Andes are made.

The concession includes the sole and exclusive operation of all international wireless telegraph stations within the Peruvian Republic, and the exclusive right to erect any further wireless stations that may be considered necessary. **[2210]**

Information from Washington indicates that the difficulties which had arisen in connection with the high-power wireless stations which the American Federal Company was to erect at Shanghai have yielded to diplomatic pressure. The work of erection is expected to occupy about eighteen months. Stations are to be erected at a later date at Canton, Pekin and Kharbin. The putting into operation of the Shanghai station should, it is believed, enable direct wireless communication across the Pacific without the intervention of relay stations. **[2274]**

VENEZUELA RADIO PLANS.—A definite programme has been established by the Venezuelan Government for the installation of twenty-two wireless stations including in particular stations at the following places: Maracay, San Cristobal, Maracaibo, Puerto Cabello, Coro, La Guaira and Ciudad Bolivar. **[2279]**

A HIGH-POWER STATION FOR WARSAW.—It is announced by the Radio Corporation of America that the new high-power station to be built by them at Warsaw (see Note No. **2368** on p. 205 of our last issue) is to be equipped with Alexanderson alternators. **[2464]**

The radio station at Cape Cod, owned by the Radio Corporation of America, has recently been opened for general public service on wavelengths of 600 and 2,200 metres, using C.W. or interrupted C.W. transmission. Call letters WCC. Coastal station charges ten cents per word, no minimum. The receiving station is located at Chatham, Mass.

A spark station has also been opened for general public service at New Brunswick, for traffic on 300, 450, and 600 metres wavelength. Call letters WYN. Coastal station charges ten cents per word, no minimum. The receiving apparatus is located at Belmar, N.J.

On and after May 1st, the station rate will be increased to eight cents per word (with no minimum) for all vessels controlled by the Radio Corporation of America. Vessels operated under contract with the U.S. Shipping Board will continue to apply the existing four cents rate. [2542]

General.

SISCONSET RADIO STATION.—A new radio station has been opened by the International Radiotelegraph Company at Sisconset, on Nantucket Island, Mass. Current for operating the plant is obtained from a storage battery which is charged when necessary by means of a gasoline-driven generator set. The transmitter is of the spark type and of 2 kW capacity. [1505]

An American radio record was scored by the U.S. Navy when the Goat Island radio station reported that messages had been sent within three minutes from Cavite, Philippine Islands, to Washington, D.C., a distance of 10,000 miles. [2288]

The radio station on the island Phu-Quoc (Cochin China) was opened for public service in November last. The tariff for messages to any telegraphic office in Indo-China is 0.05 piastre per word. [2118]

TERMINAL MARKINGS FOR ELECTRICAL APPARATUS.—A Sectional Committee has been appointed by the Engineering Standards Committee to prepare a systematic plan for the marking of the terminals of electrical apparatus. This work follows on the meeting of the Electrotechnical Commission held in Brussels in March, 1920. [2219]

It will be recalled that in the Report issued last June by the Imperial Wireless Committee it was recommended that a system of Imperial wireless communication should be established through a chain of stations 2,000 miles apart. It was suggested that the technical details of the scheme should be worked out by a special commission. The members of this body which included Lord Milner, Dr. Eccles, Mr. L. B. Turner and Mr. Shaughnessy are, with the exception of Lord Milner, now engaged in a detailed investigation of the scientific and engineering problems involved and are expected to make a report during the next two months. [2275]

HIGH-SPEED WIRELESS TELEGRAPHY BETWEEN ALDERSHOT AND COLOGNE.—A short account of special high-speed tests conducted on February 9th, 10th and 11th, at 100 words per minute. The results showed that 83 per cent. of the messages were received with perfect slip; of the remaining 17 per cent., 9 per cent. had errors which were readily corrected at sight and due primarily to maladjustment of the apparatus; and the remaining 8 per cent. contained errors which necessitated repetition. Short trials were also undertaken at 150 words per minute with good results. The transmitter consisted of a 1½-kW valve set, while at the receiver a three-valve H.F. amplifier, Turner valve relay, valve amplifier and double valve relay were employed all in cascade.—*Post Office Electrical Engineers' Journal.* [2519]

The radiotelegraphic branch of the Department of Naval Service, Canada, announces the opening of a new radiotelegraphic direction finding station near Red Head on the east side of the entrance to the harbour, and 1·93 miles from Partridge Island Lighthouse. The new station has been named St. John, N.B., Direction Finding Station and has call letters of VAR. The wavelength to be used for transmission and reception is 800 metres. [1683]

An announcement was made on March 23rd last by the President of the Radio Corporation of America to the effect that the United Fruit Company had acquired a substantial minority interest in the Radio Corporation of America and that they will be represented on the Board by Mr. George S. Davis, who has been elected a director of the Corporation. [2568]

The A.S. Norsk Marconi Kompani has declared a dividend at the rate of 5 per cent. for 1920, making with the interim distribution a total of 15 per cent. for the year. [2581]

In a "Notice to Airmen" recently issued by the Air Ministry instructions are given as to the employment by aircraft of the wireless direction finding stations established by the British Navy at nine points along the British coasts. [2055]

Review of Radio Literature.

1. Abstracts of Articles and Patents.

(A.) Radio Stations and Installations (General and Descriptive Articles).

1755. The Organisation of a Subterranean Wireless Station at Paris during the War (Trocadero Station). (*Radioélectricité*, 1, pp. 14—18, June, 1920.)
An illustrated description of the installation at the Palais du Trocadéro, Paris.

1756. **H. Sauvé.** The Radio Station at Bamako (Soudan). (*Radioélectricité*, 1, pp. 348—351, December, 1920.)
A brief description with exterior views.

1757. Remote-control Panel for Radio Stations. (*Scientific American*, 124, p. 123, February 12th, 1921. *Technical Review*, 9, p. 16, April 5th, 1921—Abstract.)
A short note *re* a new arrangement of distant control panel, but giving no technical details.

1758. Extensions to the Nauen Radio Station. (*L'Électricien*, 52, p. 133, March 15th, 1921.)
A short note giving some details of the latest installation.

1759. **W. Ison.** Rome (San Paolo) Station. (*Everyday Science*, 2, pp. 503—504, January, 1921.)
A short illustrated description.

1760. **E. W. Welch.** The Great Pre-War World Wireless Scheme in Germany. (*Telegraph and Telephone Age*, 39, pp. 102—104, March 1st, 1921. *St. Martin's le Grand*, 31, pp. 24—28, January, 1921.)
An abstract of an article published in the *Archiv für Post und Telegraphie*. See RADIO REVIEW Abstract No. 1426, February, 1921; also pp. 68—75, February, 1921; and pp. 250—261 in this issue for translation.

1761. Radio from Shanghai to Washington. (*Telegraph and Telephone Age*, 39, p. 104, March 1st, 1921.)
Reference to the high-power radio stations to be erected by the Federal Telegraph Company in China for direct communication with San Francisco and Washington. See RADIO REVIEW Note No. **1996**, p. 154, March, 1921, and No. **2274**, p. 262, in this issue.

1762. The Nauen Radio Station. (*Science and Invention*, 8, p. 880, December, 1920.)
A general illustrated description.

1763. **A. C. Forbes.** A 300 kVA Transmitter at Bolinas, California. (*Science and Invention*, 8, pp. 757 and 780, November, 1920.)
A brief illustrated description of the installation.

1764. Eilvese Radio Station. (*Science and Invention*, 8, p. 881, December, 1920.)
A short illustrated description.

1765. **S. R. Winters.** Radio Stations to Improve Air Mail Service. (*Wireless Age*, 8, pp. 12—13, January, 1921.)
A short illustrated note with regard to fifteen radio stations for use in connection with the U.S. Post Office Air Mail Service.

1766. **J. O. Smith.** Thousand-Mile Amateur Radiophone. (*Wireless Age*, 8, pp. 11—15, March, 1921.)
A detailed illustrated description of an installation at Valley Stream, L.I., U.S.A., which has communicated by radiotelephony over ranges up to 1,300 miles using an antenna current of approximately 3 amperes.

1767. Wireless Telegraphy in the Belgian Congo. (*L'Électricité pour Tous*, 2, pp. 207—213, September, 1920.)
A general illustrated account of radio developments in the Belgian Congo extracted from a book with the same title by **R. B. Goldschmidt** and **R. Braillard.**

1768. Transocean Radiotelegraphy. (*L'Électricité pour Tous*, 3, pp. 11—13, January, 1921; pp. 43—45, February, 1921.)

An illustrated article describing briefly the Alexanderson machines, and the Towyn wireless receiving station.

1769. **de Bouillane.** Wireless and the Mercantile Marine. (*Radioélectricité*, 1, pp. 280—284, November; pp. 325—335, December, 1920; pp. 443—447, February, 1921.)

General illustrated descriptions are given of Marconi and C.G.R. ship installations; and also those of the Japanese Annaka Company, the Société des Télégraphes Multiplex (system Magunna).

1770. Japanese Transmitting Station, Haranomachi. (*World Wide Wireless*, 2, p. 3, January, 1921. *Elektrotechnische Zeitschrift*, 42, p. 161, February, 1921—Abstract.)

A short note illustrating the reinforced concrete mast, 664 feet high.

1771. Quenched Spark Wireless for Ships. (*Times Engineering Supplement*, 17, No. 557, p. 106, March, 1921.)

A short note with regard to a new pattern of 1½-kW quenched-spark ship type transmitter manufactured by the Marconi Company.

1772. **J. A. Payne.** Radiophone Transmitter on the U.S.S. *George Washington*. (*General Electric Review*, 23, pp. 804—806, October, 1920.)

A short description of the installation fitted by the General Electric Company, U.S.A., on the U.S.S. *George Washington* for the use of President Wilson when crossing from France to America after the Peace Conference. See also RADIO REVIEW Abstract No. 1773.

1773. **H. H. Beverage.** Duplex Radiophone Receiver on U.S.S. *George Washington*. (*General Electric Review*, 23, pp. 807—812, October, 1920.)

An illustrated description of the receiving apparatus used on the U.S.S. *George Washington* in connection with the transmitting apparatus described in previous abstract. The arrangement of double aerials is described together with the circuit diagram of the apparatus and amplifiers.

1774. Modern Marine Wireless Apparatus. (*Electrician*, 86, p. 381, April 1st, 1921.)

A short illustrated description of quenched-spark wireless apparatus manufactured by Messrs. Siemens Brothers & Co. for marine use.

1775. **E. M. Kinney.** Radio Apparatus for Aircraft and Ground Stations. (*Proceedings of the Engineers' Society of Western Pennsylvania*, February, 1920.)

1776. Wireless Telephone for Aeroplane Stations on the London to Paris Line. (*The Times*, No. 42,428, p. 13, June 4th, 1920. *Elektrotechnische Zeitschrift*, 41, p. 759, September 23rd, 1920—Abstract.)

1777. Wireless Railroad Signals. (*Wireless Age*, 8, pp. 10—11, January, 1921. *Electrical World*, 77, p. 554, March 5th, 1921—Abstract.)

A short illustrated description of the method of signalling to railway trains in which a loop is suspended beneath the locomotive from which oscillating currents are sent by means of a three-electrode valve. A tuned circuit on the track causes indications to be given in the cab of the locomotive.

1778. **F. Limon and G. Lebaupin.** The Reception of Signals on Locomotives. (*L'Électricien*, 52, pp. 121—126, March 15th, 1921.)

The Augereau system * is described and illustrated.

1779. **L. de Forest.** Setting Up an Amateur Station. (*Experimental Science*, 1, pp. 21—23, May, 1920.)

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* See also RADIO REVIEW Abstract No. 566, July, 1920.

1780. **S. C. Hooper.** Sketch of Present Radio Situation Influence on Tactics and Strategy. (*Proceedings of the U.S. Naval Institute*, 46, pp. 1209—1218, August, 1920. *Elektrotechnische Zeitschrift*, 42, p. 87, January 27th, 1921—Abstract. *Radio-électricité*, 1, pp. 507—508, March, 1921—Abstract.)

A paper presented to the U.S. Naval Institute reviewing the whole wireless system of the U.S. Navy, including radio compass apparatus.

1781. **L. H. Maertens.** Radiotelephony in the East Indies. (*Radio Nieuws*, 4, pp. 12—16, January, 1921.)

A brief account of tests made with two ½-kW Marconi sets.

1782. **J. H. C. Harrold.** Wireless Telegraphy: Its Application and Value to the Marine Service. (*Nautical Magazine*, 105, pp. 309—311, April, 1921.)

Some statistics are given with regard to the value of wireless to the merchant service and the fitting of all lighthouses and buoys with automatic wireless transmitting apparatus is described. Some special installations send out specified combinations of signals with which ships can take bearings with their D.F. apparatus.

1783. Wireless Transmission applied to Telegraphy and Telephony by Wire. (*Technical Review*, 8, p. 190, February 22nd, 1921. Abstracted from *Export and Import Review*, Berlin, October, 1920.)

Deals with the application of triode valves to multiplex telegraphy and telephony along wires.

1784. **A. Stein.** Marine Uses of Radio. (*General Electric Review*, 24, pp. 187—189, February, 1921.)

A short article describing in a general way the various applications of radiotelegraphy and telephony, and radio direction and position finding.

1785. The Development and Commercial Application of Radio Communication. (*General Electric Review*, 23, p. 793, October, 1920.)

Editorial comment on the development of C.W. transmitters.

1786. **W. H. G. Bullard.** The Application of Radio to Navigation Problems. (*Journal of the Franklin Institute*, 190, pp. 903—904, December, 1920.)

A short abstract of a lecture delivered before the electrical section of the Franklin Institute, which summarised the chief marine uses of wireless.

1787. **T. C. Harrison.** Some Notes on Wireless Telegraphy. (*Practical Engineer*, 63, pp. 118—120, February 24th, 1921.)

A *résumé* of the historical developments of wireless telegraphy.

1788. **L. M. Dunham.** Wireless as a Hobby. (*Telegraph and Telephone Age*, 39, pp. 7—8, January 1st, 1921.)

1789. Origin and Development of Radio Service in America. (*Telegraph and Telephone Age*, 39, pp. 54—55, February 1st, 1921. *Wireless Age*, 8, pp. 13—14, February, 1921.)

A general article summarising the introduction of wireless working into America, and with Admiral **Bullard's** part in encouraging the formation of the **Radio Corporation of America.**

1790. **C. G. Crawley.** Wireless Communication. (*Telegraph and Telephone Journal*, 7, pp. 92—93, March, 1921.)

An address delivered before the Telephone and Telegraph Society of London summarising the various types of wireless communications—between ships, aircraft and fixed stations. Summaries are given under the headings Naval, Mercantile Marine, Mercantile Operators, Coast Stations, D.F. Stations, Aircraft Wireless Telephony, Imperial Chain, High-power Stations. A section is also included comparing wireless and cable communications.

1791. **J. H. Dellinger.** Long Distance Radio Telephony now Practical. (*Electrical World*, 77, pp. 142—143, January 15th, 1921. *Scientific American Monthly*, 3, pp. 157—162, February, 1921—Abstract.)

A short article summarising recent progress in radiotelephonic transmission and dealing also with the most important problems at present requiring solution—such as the elimination of disturbances and interference, the provision of a reliable calling signal and the development of the maximum possible number of multiplex routes with wire-directed radio transmission.

1792. **L. B. Atkinson.** Electrical Science and Industry. (*Journal of the Institution of Electrical Engineers*, 59, pp. 1—20, December, 1920. *Electrician*, 85, pp. 616—619, November 26th, 1920—Abstract.)

The Inaugural Presidential Address to the Institution of Electrical Engineers. In the course of the Address recent progress in wireless signalling methods is summarised.

1793. Radiotelegraphy and Telephony in 1920 and 1921. (*Electrician*, 86, pp. 94—95, January 21st, 1921.)

A general summary arranged under the following headings : The Development of the Thermionic Valve, the Development of High-powered Stations, Progress in Reception, Wireless Telephony, Progress in Arc and C.W. Stations, Commercial Items, Lines for Future Developments, the Secrecy Problem, Wireless Control Systems and the Chief Problems for the Future. In the last section the following items are included as requiring development or solution : An efficient trigger relay, a valve which operates without filament battery, high-power vacuum tubes, a more reliable form of high-frequency alternator, new limiters and X-eliminators, methods of eliminating spark interference during C.W. reception.

1794. International Radiotelegraphy. (*Electrician*, 86, p. 242, February 25th, 1921.)

An editorial note with regard to the activity in establishing high-power radio service in various countries.

1795. **A. N. Goldsmith.** Transocean Telephony. (*Telegraph and Telephone Age*, 39, p. 10, March 1st, 1921.)

A short abstract of a lecture and demonstration at the College of the City of New York, in which reference was made to recent long distance radiotelegraph and telephone communication.

1796. **C. G. Crawley.** Wireless Waves. (*St. Martin's le Grand*, 31, pp. 10—13, January, 1921. *Telegraph and Telephone Age*, 39, pp. 128—129, March 16th, 1921—Abstract.)

A popular article outlining the chief methods of wireless communication. See also RADIO REVIEW Abstract No. 1338, January, 1921.

1797. **J. O. Smith.** Amateur Spark and C.W. Transmission. (*Wireless Age*, 8, pp. 11—12, February, 1921.)

A critical comparison of the two methods of transmission.

1798. **E. F. W. Alexanderson.** Central Stations for Radio Communication. (*Telegraph and Telephone Age*, 39, pp. 2—5, January 1st, 1921. *Electrician*, 85, pp. 657—658, December 3rd, 1920. *Engineer*, 121, p. 331, March 25th, 1921.)

An abstract of a paper read before the Institute of Radio Engineers on November 10th, 1920. (See also Note No. **1828** on p. 99 of the February issue.)

(B.) Spark Gaps and Spark Transmitting Apparatus.

1799. **L. Bouthillon.** On the Charging of Condensers by an Alternating E.M.F., and their Discharge through a Spark Gap. An Investigation of the Conditions for the Production of a Musical Note. (*Radioélectricité*, 1, pp. 286—291, November, 1920 ; pp. 448—454, February, 1921 ; pp. 533—546, April, 1921.)

A very mathematical discussion not suited for an effective abstract. The original should be consulted.

1800. New Type of Radio Transmitter. (*Telegraph and Telephone Age*, 39, p. 67, February 1st, 1921.)

A new pattern of radiotelegraph transmitter is briefly described and illustrated. It is manufactured by the Wireless Speciality Apparatus Company, of Boston, U.S.A., and the special feature of interest is the provision of a magnetically controlled wave-changing switch, permitting the complete remote control of the transmitter, and the almost instantaneous change to any one of four wavelengths for which the set is adjusted.

1801. **J. D. Morgan.** Impulsive Sparking Voltages in Small Gaps. (*Philosophical Magazine*, 41, pp. 462—469, March, 1921.)

Some experimental curves of sparking voltages are included in the article.

1802. **H. E. Hallborg.** Self-cooled Quenched Gap. (*Wireless Age*, 8, pp. 19—20, February, 1921.)

Constructional arrangements and parts of this gap are described and illustrated.

1803. **F. Perrin.** On Radio Stations with Synchronous Rotary Spark Gaps. (*Radioélectricité*, 1, pp. 503—506, March, 1921.)

A mathematical discussion of the charging and discharging of a condenser synchronously with the A.C. supply, as with a rotary spark gap having the same number of teeth as there are pairs of poles on the alternator. Curves are worked out giving the maximum sparking voltage and the efficiency in terms of the ratio $L\omega/R$, as well as the variation of voltage across the condenser terminals throughout the charging period.

1804. **M. Brossier.** Undamped Oscillation Generators. (*Radioélectricité*, 1, pp. 115—127, August; pp. 175—183, September; and pp. 225—240, October, 1920.)

General descriptions are given of timed spark, arc, H.F. alternator, and valve transmitting apparatus, with illustrations of installations at some high-power stations.

(C.) Arc Apparatus.

1805. **E. W. Stone.** The Poulsen Arc. (*Proceedings of the U.S. Naval Institute*, 46, pp. 1049—1073, July, 1920. *Technical Review*, 7, pp. 357—358, December 14th, 1920.)

Gives a *résumé* of the mode of operation of arc oscillation generators, with circuit diagrams of the arrangements and good illustrations of large arc installations.

1806. **Westinghouse Lamp Company.** Continuous Wave Transmitter. (*French Patent* 505633, October 31st, 1919. Published August 3rd, 1920.)

The specification describes an oscillation generator of the arc type which consists of two main electrodes and an auxiliary mercury electrode serving for starting the arc. See also *British Patent* 135185.*

1807. The Arc Generator as an Engineering Mechanism. (*Electrician*, 85, pp. 648—651, December 3rd, 1920. *Science Abstracts*, 23B, p. 101, Abstract No. 198, March 28th, 1921—Abstract.)

A short illustrated description of the arc oscillation generators manufactured by **C. F. Elwell, Ltd.** Ten-kilowatt and 25-kW sets are illustrated together with parts of the latest type of 250-kW apparatus.

1808. **L. F. Fuller.** Duplex Operation by Two Arcs. (*Wireless Age*, 8, p. 20, January, 1921.)

An arrangement of two arc generators is described, each connected to its own aerial system so that simultaneous operation on different wavelengths may be used, or the two sets of apparatus may be operated together on the same wavelength, an additional circuit being provided for maintaining the oscillations in the two aerial networks in phase with one another. Signalling is effected by keying in this coupling circuit so that the oscillations in the two aerials are alternately thrown into and out of phase with one another.

(D.) High-frequency Alternators.

1809. **E. Blake.** The Alexanderson High-frequency Alternator. (*Wireless World*, 8, pp. 702—705, January 8th, 1921. *Telegraph and Telephone Age*, 39, p. 79, February 16th, 1921—Abstract.)

An illustrated description, covering similar ground to the article referred to in Abstracts Nos. 1209, December 1920; 1333, January 1921.

1810. **M. Latour.** The Production of High-frequency Currents by Dynamo-electric Machinery. (*Annales des Postes, Télégraphes et Téléphones*, 10, pp. 32—59, March, 1921.)

This paper contains practically the same material as those referred to in Radio Review Abstract No. 781, September, 1920. See also Radio Review, p. 491, July, 1920.

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* Radio Review Abstract No. 407, June, 1920.

1811. **J. Béthenod.** On the Self-excitation of Alternators by means of a Capacity. (*Radioélectricité*, 1, pp. 187—188, September, 1920.)

A short mathematical treatment of the subject based on Blondel's theory.

(E.) Static Frequency Raisers.

1812. **J. Zenneck.** The Theory of the Magnetic Frequency Transformer. (*Jahrbuch Zeitschrift für drahtlose Telegraphie*, 17, pp. 2—21, January, 1921.)

An abstract of a paper which was read in New York in 1915. It has appeared in full in *Proceedings of the Institute of Radio Engineers*, 8, pp. 468—492, 1920. (RADIO REVIEW Abstract No. 1436, February, 1921.)

(F.) Thermionic Valves (and Valve Apparatus).

(1) AND (2) GENERAL DESCRIPTIVE ARTICLES.

1813. **L. de Forest.** The Audion: Its Action and some Recent Applications. (*Journal of the Franklin Institute*, 190, pp. 1—38, July, 1920. *Bulletin de la Société Belge des Électriciens*, 34, pp. 243—245, October, 1920—Abstract. *Science Abstracts*, 23B, p. 496, Abstract No. 946, October 31st, 1920—Abstract. *Radio News*, 2, pp. 208—210, October, 1920; pp. 280—282 and 333—335, November, 1920; and pp. 358—359, 386 and 388, December, 1920.)

A general historical account of the development of the audion followed by a consideration of the theory of electronic emission from hot filaments and some of the uses of three-electrode valve apparatus. Various radio sets using audions are illustrated and also several patterns of three-electrode tube.

1814. **H. J. van der Bijl.** Electron Relays as Amplifiers and Oscillators. (*Popular Science Monthly*, 96, pp. 132, 134, 136 and 137, April, 1920; pp. 132, 134, May, 1920; pp. 142 and 144, June, 1920.)

A popular descriptive article.

1815. Notes on the Three-electrode Valve. (*Model Engineer*, 43, pp. 406—408, November 18th, 1920; pp. 473—474, December 9th, 1920.)

A general descriptive article dealing with the various uses of the triode valve.

1816. **M. Brossler.** The Vacuum Tube in Radiotelegraphy. (*Radioélectricité*, 1, pp. 19—32, June; pp. 82—91, July, 1920.)

A general account of the multitudinous applications of two- and three-electrode valves, with illustrations of a number of types of French amplifiers, etc. Different types of valves are illustrated, with characteristic curves.

1817. Electronic Vacuum Tubes. (*L'Électricité pour Tous*, 3, pp. 75—77, March, 1921; pp. 107—109, April, 1921.)

A short general article with illustrations of typical patterns of valves.

1818. **Société Française pour l'Exploitation des Procédés Thomson-Houston.** Valve Detector. (*French Patent* 506594, November 26th, 1919. Published August 25th, 1920.)

Valves for receiving wireless signals have their anode circuits energised by the same battery as is used for heating the filaments—the voltage being preferably about six volts. The anode is a metal which is electro-positive to the filament.

There is a corresponding British application, No. 147816, of July 9th, 1920, the patent on which has not yet been granted. (British Thomson-Houston Company, assignees of **W. C. White.** Convention date October 11th, 1917.)

1819. **P. H. Boucheron.** Two New Vacuum Tubes. (*Wireless Age*, 8, pp. 15—16, February, 1921. *Electrical World*, 77, p. 498, February 26th, 1921—Abstract.)

A description of two new three-electrode vacuum tubes manufactured by the Radio Corporation of America.* A number of circuit diagrams are also given of various arrangements of amplifier.

* See also RADIO REVIEW Note No. **2170**, pp. 152 and 154, March 1921.

1820. **J. Scott-Taggart.** The Use of Vacuum Tubes for Wireless Transmission and Reception of Continuous Waves. (*Journal of the Institution of Electrical Engineers*, 58, pp. 893—897, September, 1920.)

The paper is divided into two parts dealing respectively with the use of vacuum tubes for generating oscillations and a discussion of some modern methods for receiving C.W. signals by using the heterodyne principle. A second paper is also devoted to the production of high voltages for transmission circuits and the use of D.C. dynamos, induction coils and rectified alternating current is discussed.

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(3) THEORY AND PHYSICS OF THERMIONIC VALVES.

1821. **S. L. Ting.** Experiments on Electron Emission from Hot Bodies. (*Proceedings of the Royal Society*, 98A, pp. 374—391, February 2nd, 1921. *Chemical News*, 120, p. 272, June 4th, 1920—Abstract. *Nature*, 105, p. 441, June 3rd, 1920—Abstract.)

Experiments are described designed to be a continuation of experiments on the electron currents from metal discs and filaments made by Professor Richardson in 1907. In 1914 Schottky found a distribution of energy of the electrons from tungsten and carbon filaments to be in close accordance with Maxwell's law and the present experiments show that deviations from Maxwell's law if not general are at any rate quite common. With lime-coated platinum the emission energy is either exceptionally low or else the method of investigation gives illusory results. Data are also given showing interesting hysteretic effects in the electron currents. Possibly such effects indicate the presence of residual gas and the deviations from Maxwell's law may be in some way connected with such contamination.

1822. **H. W. King.** Calculation of the Constants of the Three-electrode Thermionic Vacuum Tube. (*Physical Review*, 15, pp. 256—268, April, 1920. *Science Abstracts*, 23A, p. 432, Abstract No. 1091, August 31st, 1920—Abstract.)

This paper has already been abstracted—RADIO REVIEW Abstract No. 423, June, 1920.

1823. **I. Langmuir.** Fundamental Phenomena in Electron Tubes having Tungsten Cathodes. (*General Electric Review*, 23, pp. 503—513, June, 1920; pp. 589—596, July, 1920. *Electrical World*, 76, p. 249, July 31st, 1920, and p. 537, September 11th, 1920—Abstract. *Technical Review*, 7, p. 221, November 16th, 1920—Abstract. *Science Abstracts*, 23A, p. 585, Abstract No. 1471, November 30th, 1920—Abstract. *L'Elettrotecnica*, 8, pp. 15—16, January, 1921—Abstract.)

The author discusses the fundamental factors including the operation of two and three-electrode electron tubes—such as the electron emission from the filament, the effect of space charge, the disturbances caused by the current passing through the filament, the effects due to the electrostatic charge upon the walls of the bulb, the effects caused by lack of uniformity in the temperature of the filament and the effects of external magnetic fields. The second part of the article discusses primarily the emission of secondary electrons from the walls of the bulb and from the electrodes. Typical characteristics are given for different conditions of operation and finally the effect of the grid in a three-electrode valve is considered mathematically.

1824. **A. Blondel.** Graphical Theory of Audion Generators and the Calculation of the Amplitude of the Oscillations. (*Radioélectricité*, 1, pp. 7—13, June, 1920; pp. 63—72, July, 1920; also p. 340, December, 1920.)

Covers similar ground to the articles referred to in Abstracts Nos. 352, May; 418, 419 and 422, June, 1920.

1825. **H. Vogel** and **M. Wien.** Acoustic Tongue Pipes and Triode Oscillations. (*Annalen der Physik*, 62, pp. 649—665, August 4th, 1920. *Jahrbuch Zeitschrift für drahtlose Telegraphie*, 17, pp. 56—57, January, 1921.)

An experimental study and discussion of the analogous phenomena occurring in tongue pipes and in triode oscillators with coupled oscillatory circuits. The phenomena known as "Ziehen," *i.e.*, the occurrence of the sudden phase change at different values of the tuning condenser according as its capacity is being increased or decreased, is shown to have its exact analogy in the acoustic experiment.

1826. **F. H. Newman.** Absorption of Gases in the Electric Discharge Tube. (*Proceedings of the Physical Society of London*, 33, pp. 73—82, February 15th, 1921.)

A continuation of previous work. (See RADIO REVIEW Abstract No. 656, August, 1920.) It is concluded that the absorption is principally chemical in nature, and that it takes place very rapidly at clean freshly deposited metal surfaces.

(R.) Radio Direction Finding.

1827. **R. Mesny.** The Diffraction of the Electromagnetic Field by a Cylinder. (*Science Abstracts*, 23B, p. 495, Abstract No. 940, October 31st, 1920.)

See RADIO REVIEW, 1, pp. 532—540, August, 1920; and pp. 591—597, September, 1920.

1828. Telephoning over High-tension Lines. (*Scientific American*, 125, p. 544, November 27th, 1920.)

A brief reference to an installation of wired wireless telephony over a 11,000-volt line between Ocean City and Atlantic City, N.J.

1829. **W. Burstyn.** Wireless Telegraphy in Space. (*Jahrbuch Zeitschrift für drahtlose Telegraphie*, 16, pp. 322—337, November, 1920.)

The problem of transmission between an aeroplane and a ground station is considered. The trailing aerial of the former is taken as being equivalent to a Hertzian oscillator inclined at about 20 degrees to the horizontal. Because of this position it shows a very strong directional action which leads to a complicated spacial characteristic. The received current is also dependent on the aerial arrangement of the ground station. The relation between the received current and the spacial relations of the aerials is written

$$S = k \cdot \frac{1}{b} \cdot \sin \xi \cdot \sin \eta$$

where S is the received current, k is a constant, b the distance between the stations, ξ the angle between the axis of the sending oscillator and the direction of radiation, and η the angle between the electric vector and the direction of the receiving Hertzian oscillator. Various special cases of this characteristic formula are discussed in detail (*e.g.*, the case in which the aeroplane while sending maintains a constant direction at constant height, or the case in which the aeroplane turns at an approximately constant distance, etc.). The possibility of errors in taking directional bearings on an aeroplane transmitter of this type is considered briefly, a further discussion being postponed for a later paper.

1830. **J. Hollingworth** and **B. Hoyle.** Local Errors in Radio Direction Finding. (*Technical Review*, 7, pp. 427—428, December 28th, 1920—Abstract.)

See RADIO REVIEW, 1, pp. 644—649, October, 1920.

1831. **G. Ferrie, R. Jouaust, R. Mesny** and **A. Perot.** Radiogoniometric Investigations. (*Comptes Rendus*, 172, pp. 44—57, January 3rd, 1921.)

The results of observations carried out by a special D.F. observing station erected at Meudon are set out briefly. The observations were made on signals from Lyons, Hanover, Rome, Nantes, Annapolis, Clifden and Moscow, and a chart is included summarising some large variations in apparent direction from the Hanover station. These variations were accompanied by bad minima of signal strength and their magnitude varied with the season of the year.

1832. **J. H. Dellinger.** The Radio Compass. (*Radio Amateur News*, 1, pp. 400—402, February, 1920.)

A general descriptive article.

1833. The European Direction-finding Stations. (*Radioélectricité*, 1, pp. 38—39, June, 1920.)

Includes tabular particulars of the principal British, French and German D.F. stations with a chart showing their positions.

1834. Marine Direction Finding. (*Radioélectricité*, 1, pp. 33—35, June, 1920.)

1835. The Determination of a Ship's Position by means of Wireless Telegraphy combined with Submarine Sound Signals. (*Radioélectricité*, 1, p. 256, October, 1920.)

1836. **L. Fave.** Marine and Aerial Navigation. (*Comptes Rendus*, 172, pp. 252—254, January 31st, 1921.)
Includes some references to the uses of W/T.

1837. **J. Erskine-Murray** and **J. Robinson.** Wireless Direction-finding Apparatus. (*French Patent* 505571, October 29th, 1919. Published August 2nd, 1920.)
In order to enable vessels and aircraft to determine the direction of a transmitting station, it is proposed to provide the station with means for sending out signals in pairs at a definite angle apart, and means to provide that the signals are sent out in pairs in different directions.
See also *British Patent* 135896, RADIO REVIEW Abstract No. 505, July, 1920.

(S.) Distant Control by Wireless.

1838. **E. T. Jones.** Torpedo Controlled by Aeroplane. (*Wireless Age*, 8, pp. 30—31, October, 1920.)
Circuit diagrams of an arrangement due to **E. C. Hanson** are given. The torpedo carries an antenna suspended by a balloon.

1839. Radio Control of Naval Units. (*Scientific American*, 123, p. 442, October 30th, 1920.)

1840. Radio Control for Aeroplanes. (*Scientific American*, 123, p. 402, October 16th, 1920.)
A short note referring to the use of radio means for controlling pilotless aircraft.

(T.) High Frequency Wire Telegraphy and Telephony.

1841. **F. E. Pernot.** The Use of Alternating Currents for Submarine Cable Transmission. (*Journal of the Franklin Institute*, 190, pp. 323—371, September, 1920. *Electrical World*, 76, p. 792, October 16th, 1920—Abstract.)
Experiments with wired wireless communication for the Alaskan submarine cable system are described. Extended tables of measurements and other data are included together with curves of capacity attenuation constants and other similar factors.

1842. **J. Corver.** High Frequency Wire Telephony. (*Radio Nieuws*, 3, pp. 267—270, September, 1920.)

1843. **H. Fassbender,** and **E. Habann,** Circuit for High Frequency Line Telegraphy. (*German Patent* 312590, September 25th, 1918.)
A "wired wireless" circuit in which the transmitter also serves to generate the local oscillations required for beat reception (see Fig. 1).

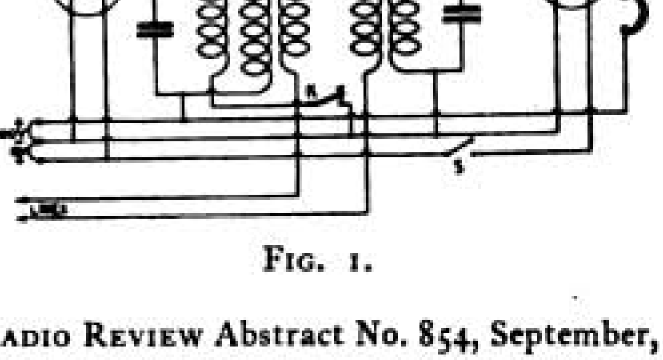

FIG. 1.

1844. **J. W. Kean.** Wired Wireless Experiments in the United States. (*Radio News*, 2, p. 134, September, 1920.)
A *résumé* of **G. O. Squier's** experiments. (See RADIO REVIEW Abstract No. 854, September, 1920.)

1845. **A. Gradenwitz.** Wired Wireless Experiments in Germany. (*Radio News*, 2, pp. 135 and 164, September, 1920.)
A *résumé* of Fassbender and Habann's experiments. See RADIO REVIEW Abstracts Nos. 1146 and 1179, November, 1920.

(U.) Miscellaneous Methods of Communication.

1846. **T. W. Case.** Thalofide Photoelectric Cell. (*Electrical World*, 76, p. 1033, November 20th, 1920.) Also The Thalofide Cell, a New Photoelectric Substance. (*Physical Review*, 15, pp. 289—292, April, 1920. *Science Abstracts*, 23A, p. 587, Abstract No. 1477, November 30th, 1920—Abstract.)

A short note describing experiments on the use of new thalofide cells for photophonic transmission. An acetylene flame transmitter was employed.

1847. **H. Barkhausen** and **H. Lichte.** Quantitative Experiments on Sound under Water. (*Annalen der Physik*, 62, pp. 485—516, July 16th, 1920. *Science Abstracts*, 23A, pp. 577—578, Abstract No. 1456, November 30th, 1920—Abstract.)

1848. Leader Cables for Navigation. (*Times Engineering Supplement*, 17, No. 555, p. 32, January, 1921.)

An account is given of a demonstration of the apparatus installed at Portsmouth.

1849. **E. T. Jones.** Convoying Ships by Radio. (*Experimental Science*, 1, p. 7, May, 1920.)
Apparatus is described for guiding ships by a submerged cable.

(V.) Traffic Particulars of Radio Stations.

1850. The Development of Radio Traffic in Germany. (*Annales des Postes, Télégraphes et Téléphones*, 9, p. 593, December, 1920.)

A brief *résumé* of radio traffic from June, 1919, to June, 1920.

1851. The Reception and Transmission of Meteorological Bulletins for Ships. (*Radioélectricité*, 1, pp. 298—300, November, 1920.)

Tables are given of the principal stations circulating such reports.

1852. The Programmes of Press Transmission. (*La Nature*, 48(2), Supplement p. 183, December 4th, 1920.)

Particulars are given of the leading European high-power stations.

1853. German Wireless Press Service. (*Telegraphen- und Fernsprech-Technik*, 9, pp. 149—150, December, 1920.)

A description of experiments in the distribution of wireless news by telegraphy and telephony from Königswusterhausen which is fitted with a 1-kW valve transmitter (300 watts in antenna).

1854. **G. Bigourdan.** Corrections to the Normal Time Signals transmitted by the International Bureau de l'Heure between January 1st and March 19th, 1920. (*Comptes Rendus*, 171, pp. 600—605, October 4th, and pp. 643—645, October 11th, 1920.)

Tables are given of the corrections to the standard pendulum by which the transmission of the time signals is controlled, and also of the errors of the wireless telegraphic transmission.

1855. The Nantes Radio Station. (*Radioélectricité*, 1, p. 421, January, 1921.)

A short note stating that four new 180-metre towers are to be added to this station, enabling transmission to be effected with wavelength between 11,000 and 20,000 metres.

1856. Wireless Telephone to Geneva. (*The Times*, No. 42592, p. 7, December 13th, 1920.)

A report relative to wireless telephone transmission tests between London and Geneva *via* Chelmsford radio station. Speeches were sent to Geneva by Lord Burnham, Lord Riddell and Dr. Graham Bell speaking on an ordinary landline telephone instrument.

(W.) Radio Legislation (Agreements, Patents, etc.).

1857. International Communications Conference. (*Telegraph and Telephone Age*, 38, pp. 592—593, November 16th, 1920.)

Reference is made to the visits of the international delegates to the radio plants in the vicinity of New York.

1858. **P. Brenot.** International Radio Legislation. (*Radioélectricité*, 1, pp. 154—165, August; pp. 211—216, September, 1920.)

A summary of the main international laws fixed by the radio conventions, and now in force.

1859. An International Postal, Telegraphic, and Radiotelegraphic Conference. (*Radio-électricité*, 1, pp. 108—111, July; pp. 168—169, August, 1920.)
A report of a conference held in Paris in July, 1920.

1860. Japanese Regulations concerning the Transmission of Public Correspondence by Private Telegraph Stations or by Private Radio Stations. (*Journal Télégraphique*, 44, pp. 127—130, August 25th, 1920. *Radioélectricité*, 1, p. 362, December, 1920; pp. 419—420, January, 1921.)

1861. Australian Wireless Restrictions. (*Electrical Review*, 87, p. 80, July 16th, 1920.)
Reference is made to the conditions under which wireless telegraph licences are granted.

1862. French Radio Legislation. (*Radioélectricité*, 1, pp. 52—55, June; pp. 102—104, July, 1920; also p. 165, August, 1920.)
A detailed statement of the French radio laws at present in force.

1863. British Radio Legislation. (*Radioélectricité*, 1, pp. 267—272, October, 1920.)
A summary is given of the laws at present in force.

1864. The Reception of Time Signals and Meteorological Telegrams in France. (*Radio-électricité*, 1, pp. 310—312, November, 1920.)
Details of legislation for this class of radio work.

1865. Wireless Telegraphy and Aerial Navigation. (*Radioélectricité*, 1, pp. 216—217, September, 1920.)
A summary of the French laws bearing on this phase of radio work.

1866. Wireless Telegraphy in Colombia. (*Electrical Review*, 87, p. 274, August 27th, 1920.)
Reference is made to a contract between the Colombian Government and Marconi's Wireless Telegraph Company for the erection of stations.

1867. Argentine Wireless. (*Elektrotechnische Zeitschrift*, 42, p. 42, January 13th, 1921. Abstracted from *Lateinamerika*, (A), pp. 230—231, 1920.)
Details of various interests which have obtained concessions for the erection of high-powered wireless stations in Argentine, but more especially of a German company founded jointly by Siemens and the A.E.G. under the name of the "Compania Radiotelegrafica Transradio" with the object of liberating South America from the English cable monopoly.

(X.) Biographical and Personal Notes.

1868. **D. C. Jackson.** Dr. Elihu Thomson—Scientist, Inventor and Educator. (*General Electric Review*, 23, pp. 983—984, December, 1920.)
A biographical sketch.

1869. **Thomas Thomassen Heftye.** (*Telefunken Zeitung*, 4, No. 21, pp. 3—4, July, 1920.)

1870. M. **Jules Carpentier.** (*Radioélectricité*, 1, pp. 5—6, June, 1920.)

1871. General **Messimy.** (*Radioélectricité*, 1, pp. 173—174, September, 1920.)
A short biographical notice with portrait.

1872. M. **Édouard Branly.** (*Radioélectricité*, 1, pp. 277—279, November, 1920.)
Some biographical notes, including a photographic reproduction of a wireless message received by M. **Branly** from Mr. **Marconi** on March 28th, 1899.

1873. M. **E. Brylinski.** (*Radioélectricité*, 1, pp. 323—324, December, 1920.)
Biographical notes.

1874. **L. Amaduzzi.** The Scientific Work of Professor **Righi.** (*Revue Scientifique*, 58, pp. 524—527, September 11th, 1920. *Scientia*, 28, pp. 467—472, December 1st, 1920.)

1875. **A. Righi.** (*Radioélectricité*, 1, pp. 223—224, October, 1920. *Elektrotechnische Zeitschrift*, 41, p. 598, July 29th, 1920. *Comptes Rendus*, 171, p. 1251, December 20th 1920.)
Obituary notices.

1876. **M. R. de Valbreuze.** (*Radioélectricité*, 1, p. 240, October, 1920.)
A note with regard to the nomination of M. de Valbreuze as Chevalier of Legion of Honour.

(Y.) Historical Radio Articles.

1877. A Short History of Primitive Methods of Visual Signalling. (*Telegraph and Telephone Age*, 38, pp. 568—570, November 1st, 1920.)

1878. Seventy-five Years of Applied Electricity. (*Scientific American*, 123, pp. 331—333, October 2nd, 1920.)
Contains a brief review of telegraphic development from 1845 to the high power radio station of to-day.

1879. Electrical Engineering in 1920. (*Engineer*, 131, pp. 18—20, January 7th, 1921.)
A *résumé* of the most important wireless developments in 1920 is included.

1880. Telegraphy and Telephony (in Germany) Before, During and After the War. (*Archiv für Post und Telegraphie*, pp. 1—31, January, 1921.)
A review containing a section devoted to wireless.

(Z.) Miscellaneous Applications of Radio. Radio Nomenclature, etc.

1881. **F. H. Sykes.** Civil Aviation and Air Services. (*Aeronautical Journal*, 24, pp. 579—594, November, 1920. *Engineer*, 130, pp. 385—386, October 15th, 1920—Abstract. *Wireless World*, 8, p. 575, November 13th, 1920—Abstract. *The Electrical Review*, 87, pp. 603—604, November 5th, 1920.)
Includes some reference to the utility of wireless for aircraft services.

1882. Airplane and Flight Conditions. (*Everyday Engineering Magazine*, 10, p. 59, October, 1920.)

1883. Wireless Time Signals. (*Technical Review*, 87, p. 755, December 10th, 1920.)
Wireless telegraph equipment is being installed at the Huddersfield tramway offices, to pick up the Eiffel Tower (Paris) standard time signals. A governor clock has been fixed, and the tramway clock will be checked each day by the Paris message.

1884. **P. Schereschewsky.** Wireless and Meteorology. (*La Nature*, 49, (1), pp. 12—16, January 1st, 1921.)
A chart is given showing the position of the French meteorological stations and of the wireless communication routes used therewith; together with tables of the weather reports circulated by wireless containing the observations made at these stations. A chart is also given of the meteorological network for the whole of Europe.

1885. **J. Bethenod.** An Investigation of the Electrical and Radio Methods of Repeating Signal Indications on Locomotives. (*Radioélectricité*, 1, pp. 292—297, November; pp. 341—347, December, 1920.)

1886. Wireless Telephony as Police Aid. (*Electrical World*, 77, p. 60, January 21st, 1921.)
Refers to the use of wireless telephone apparatus in connection with police squads using automobiles.

1887. Christiania. (*Elektrotechnische Zeitschrift*, 42, p. 189, February 24th, 1921.)
A letter from **W. Dornig** of the Telefunken Company protesting against the adjective "gross" being applied to this station in a recent article, since its antenna power is only about 15 kW. He also states that it does not represent the best modern practice.

1888. The Bureau of Standards Radio Classification. (*Everyday Engineering Magazine*, 9, pp. 356—358, July, 1920.)
Full details are given of the proposed classification for information on radio subjects.

1889. Standardising Radio Nomenclature. (*Everyday Engineering Magazine*, 10, pp. 66—67, October, 1920.)

Suggestions are made for a standardised lettering for the terminals and parts of radio apparatus. Some of the abbreviations given are also applicable to drawings and references in articles.

1890. **Ajax Metal Company.** Receiving Apparatus. (*French Patent* 496120, filed July 23rd, 1919. Dated October 28th, 1919.)

This specification describes a method of induction heating by the use of high frequency currents as obtained, for example, by a condenser discharge. The primary winding of the furnace is shown connected to supply conductors through a condenser in one conductor and inductances in both conductors. The conductors are shunted by a spark gap arranged between two pairs of inductances. An arrangement for polyphase working is also shown and it is stated that the arrangement is applicable to wireless telegraphy.

2. Books.

WIRELESS TELEGRAPHY AND TELEPHONY: An Outline for Electrical Engineers and Others. By L. B. Turner, M.A., M.I.E.E. (London: *The Cambridge University Press*. 1921. 8½" × 5½". Pp. xii + 195. Price 20s. net.)

In this book the author sets out to " provide for the large class of interested persons occupying an intermediate position " between " the wireless operator on the one hand and the specialist wireless engineer on the other." The subject is a large one and as usual some compromise has had to be made between the matter to be included and the space available. Different individuals rarely agree on a compromise of this kind but in the present instance it is difficult to find any serious fault with the author's choice. The book is one that can be read by any one who has reached the standard of a third year electrical engineering student and in some chapters one can almost hear the author holding forth to his undergraduates at Cambridge. The subject-matter is put forward in an accurate and interesting way, parts of the book reading like an enthralling novel! The very latest and most recent practice in wireless is discussed and a good sense of perspective is maintained throughout. Occasionally the author allows himself to look ahead and to express opinions on the probable lines of future advance and for this reason the book is one which will appeal to " specialist wireless engineers " although, as stated previously, it is not primarily intended for them. As is natural, detailed descriptions of instruments and machinery and matters of a purely practical nature occupy but a small proportion of the space. The book is well produced and the repetition of Fig. 45 is an example that might well be generally adopted where an intricate line of argument extends from one page to another. The arrangement of the plates is hardly as convenient as it might have been but was determined no doubt by considerations of the cost of production.

The book opens with a short introduction followed by a chapter on Electromagnetic Waves. The difficulties of this subject are admitted on all hands and perhaps the author is well advised to approach the subject as he has done, but it must be confessed that the earlier parts of this chapter are unconvincing and do little beyond restating the difficulties. The working idea of, at any rate, the plane electromagnetic wave might have been more fully developed. After a chapter on the General Theory of Oscillatory Circuits, the Spark, Alternator and Arc methods of generating oscillatory currents are described in a readable chapter that contains the essentials of the respective methods without going into excessive detail. The fifth chapter deals with methods of detecting small oscillatory currents, after which the author can no longer restrain himself but plunges into his main theme, viz. the Thermionic Tube. An excellent description of the two and three-electrode valves is followed by a chapter on Amplifiers, the opening of which seems a little unnecessarily abrupt and is unfortunately marred by a wrong page reference. The principles and uses of the various types of valve amplifier are well described, but the all-important effects of " reaction " are relegated to a later chapter. The next chapter treats of the valve as a rectifier of small currents purely in connection with the reception of signals. The use of the " Triode as an Oscillation Generator " follows in Chapter IX., which appears to fall somewhat below the standard of those preceding it. The " simplified case " dealt with in the first instance is really of little assistance and, if anything, makes more difficult the understanding of the actual conditions. The discussion of the limits of amplitude of the oscillation is not easy to follow, and it is unfortunate that the family of $I_a - V_g$ curves is chosen for this purpose instead of the $V_a - V_g$ constant current contours. With the aid of the latter this apparently rather difficult question becomes quite clear. The chapter ends with a short account of the circuits as used for transmitting purposes, including a brief mention of high-power rectifiers. The use of " reaction " naturally follows, and its application in receiving circuits and amplifiers is clearly described. A good account of Wireless Telephony is then given, but the differences between wireless telephony and telegraphy are perhaps rather over-accentuated. The last chapter is a miscellaneous one and after discussing the need of devising some means of overcoming atmospheric interference the author says, "When the fight against atmospherics has been won . . . π times the radius of a well-ordered world will be the *maximum* range of the stations on it "—a statement with which no one will quarrel !

C. L. FORTESCUE.

Books Received.

THE ELECTRICAL TRANSMISSION OF PHOTOGRAPHS. By Marcus J. Martin. (London : *Sir Isaac Pitman & Sons, Ltd.* 1921. 7" × 4½". Pp. vi + 136. Price 6*s.* net.)

THE " PRACTICAL ENGINEER " ELECTRICAL POCKET BOOK AND DIARY, 1921. (London : *The Technical Publishing Co., Ltd.* 1921. 5¼" × 3¼". Pp. ciii + 610 + 48. Price 2*s.* 6*d.* net. Post free 3*s.* Abroad 3*s.*)

ARITHMETIC OF TELEGRAPHY AND TELEPHONY. By T. E. Herbert, A.M.I.E.E., and R. G. de Wardt. (London : *Sir Isaac Pitman & Sons, Ltd.* 1921. 7" × 4½". Pp. vii + 187. Price 5*s.* net.)

RELATIVITY AND THE ELECTRON THEORY. By E. Cunningham. (London : *Longmans, Green & Co.* 1921. 8¾" × 5¾". Pp. vii + 148. Price 10*s.* 6*d.* net.)

Correspondence.

ARC *VERSUS* ALTERNATOR FOR HIGH POWER WORK.

TO THE EDITOR OF THE " RADIO REVIEW."

SIR,—The author has much to say upon the defects of the arc, but nothing at all to say upon the defects of the H.F. alternator.

The compensation method of signalling has been almost exclusively used in the past, but recently a considerable amount of work has been done upon the suppression of the compensation wave and the emission of a single wave. The problem is not insoluble and has not been seriously attacked sooner because there has been no call for it, due to the small number of high-power stations in operation. One of the needs of the future is the speeding up of transmission in order that a given station will occupy the ether for a lesser time interval. The change of antenna current from maximum to zero at a high rate will probably cause more interference than the small change of wavelength which it is now possible to use, when transmitting from arc stations to stations with good receivers. The small difference between the compensation and telegraph wavelengths from the arc station at Rome should be noted, and this station handles a minimum of 10,000 words per diem of commercial traffic to Bucharest, Constantinople, Massowa, Sweden, England and America.

The necessity of cleaning the arc chamber is true to a certain extent, but it has not been found necessary heretofore to supply three arcs for this reason. Attention may also be drawn to a statement contained in the Report of the Imperial Wireless Telegraphy Committee, 1919—20 : " Any good working electrician can run an arc ; a skilled engineer must be in charge of a high-frequency alternator."

Aerial insulators are now available to take care of the maximum aerial voltages with an ample factor of safety.

Large arc installations are readily made to give an efficiency of 48 per cent. The auxiliaries are practically *nil*, whereas alternators call for vacuum and oil pumps, etc.

The absence of moving parts in an arc generator and the ability to change any part, which might prove defective, within the space of an hour or less contrasts favourably with the days and weeks which must elapse in order to repair a large high-power high-frequency alternator, especially when considering installations in the remote tropics.

Upwards of 20,000 kW of arc generators are now doing good service in various parts of the world, and if questions of first cost and upkeep are carefully studied the arc generator is still able to hold its own.

C. F. ELWELL.

London.
April 13th, 1921.

ARC *VERSUS* ALTERNATOR FOR HIGH POWER WORK.

To the Editor of the "Radio Review."

SIR,—The author's suggestion that the arc is becoming obsolete as a high-frequency generator for use in wireless telegraphy hardly gives a just idea of the situation. The alternator is still comparatively in an experimental stage and has yet to prove its practical worth, particularly for work in the colonies. No doubt improvements are to be expected in the future.

High-power arc transmitters have been in regular service for five to six years. During this period considerable improvements have been made in their design and are still going on. Harmonics are being avoided by use of suitable field strength and by the provision of absorption circuits. Suitable aerial constants contribute also considerably to the reduction of harmonics.

The sooting which occurs with illuminating gas, or kerosene, is greatly reduced when alcohol, evaporated in a suitable vaporiser, is employed.

The use of the spacing wave, the length of which differs from the signalling wave by less than 1 per cent. and not 2—3 per cent., is not such a serious disadvantage as the author suggests, and it is by no means certain that the International Conference will suppress it. It necessitates the use by a station of a wider (by 1 per cent.) band of allocated wavelengths, but arc transmission without spacing wave is being experimented with for higher powers, and the problem is not of a kind which is insoluble. If these costly experiments were delayed in the past, it was because the number of high-power stations was not great enough to render this problem really important.

At present, as in the past, the arc is the most reliable H.F. generator. It does not require highly trained attendance, as the H.F. alternator. It is robust, and there is not the risk of serious breakdown, which in the case of an alternator may put the machine out of action for weeks or months.

Two arcs ensure a regular uninterrupted service. It is doubtful whether as much can be said for the H.F. alternator.

One very important advantage of the arc over the alternator is the wide range of wavelengths (from 1 to 4). If suitable field strengths be used the reduction of power for the shorter wavelengths is not very large.

As to the exceptional excess voltages due to the irregularities of the arc, it is to be noted that, although the voltage across the arc may be irregular, the same does not occur as regards the voltage across the aerial insulators, and no greater insulator trouble is experienced with the arc than with the alternator for the same aerial currents.

The above remarks are based on actual working experience with 200 and 450 kW arc generators.

J. MAMLOK.

London.
April 13th, 1921.

A METHOD OF DIRECTION FINDING.

To the Editor of the "Radio Review."

SIR,—With reference to Major Erskine-Murray's letter in your last issue.

Ruskin complained of the impossibility of writing even the plainest English that could not be misconstrued ; careful statement sometimes fails simply by loss of the over-emphasis, to which journalism has accustomed us. I trust that my article did not convey to other readers that I rated " convenience or accuracy " of no account in practical work. A thing may be secondary, that is, derived, or dependent, without being unimportant. For instance, whether you eat your lunch or not is a primary fact; whether you digest it is a secondary one, but failure in the latter sphere of human activity may be more distressing than failure in the former!

The term " secondary considerations " was seriously and accurately meant. The primary fact is the mathematical nature of the curve of the simple loop; convenience (for instance, the preferred use of a comparatively narrow angular swing reading, passing through silence, to a wider swing passing through louder sound) and accuracy (for instance, the preferred use of a rapidly changing portion of the curve) are derived or resulting things—not unimportant, but still derived or secondary. Major Erskine-Murray rather misquotes me by omitting the context, and also the complementary words ". . . this constant signal *within the limits of searching* . . ."

Priority of results does not really enter into the question. During 1917, before the formation of the amalgamated Air Force, it was definitely decided at one of the joint meetings, to avoid overlapping, to leave the development of D.F. in aeroplanes to the R.N.A.S. (who were specialising in Captain Robinson's method) and wireless telephony in aeroplanes to the R.A.F. (who had originated it). It is not surprising, therefore, that the earliest results were got by the only workers in the field thus left open to them, by the only system which they were practising.

No undue stress was intended to be laid on the patents mentioned. Major Erskine-Murray is right in pointing out that they suffer from the fundamental defect of " 4 degrees of ambiguity," exactly as does the Robinson system; but is he content thus to dismiss the latter, under the same condemnation?

The substitution of switching for rotation, as in Captain Round's method mentioned on p. 698, was an old device of D.F. experimenters long ere Captain Robinson's ingenious application of it.

I do not think it is a just inference from Captain Round's I.E.E. paper, that a " formidable train of errors " arises from the " more complicated " Bellini circuits.

I find it difficult to analyse my opponent's persistent scorn of the " minimum method." My whole argument was that both the contrasted systems employed a (why " rough "?) comparison of signal strength on each side of the minimum, but in different ways. Both use the minimum; why kick the poor thing when it's at zero?

In conclusion, my critique was not an attack on Captain Robinson's method, but was an attempt to remove certain current misconceptions about it and to set it in its due perspective with respect to earlier and other work. I think that the careful and unbiassed reader of the inventor's exposition, taken in conjunction with my critique, should be in a good position to form a balanced judgment of its place in this special field of radio work, and of what it holds both of good and bad, and perhaps it would be best to allow the articles to speak for themselves, until experiment reveals new facts, or throws some new light on this portion of a most interesting subject.

C. E. PRINCE.

Burchett's Green, Berks.
April 6th, 1921.

THE HETERODYNE METHOD OF WIRELESS RECEPTION, ITS ADVANTAGES, AND ITS FUTURE.

TO THE EDITOR OF THE " RADIO REVIEW."

SIR,—Mr. Round may well rest assured that the objections he raises have occurred to myself.

I knew from experiments that I have made myself that acoustic resonance gives no appreciable results against atmospherics in the case of reception of damped waves emitted by a musical spark. The reason of it, in my opinion, is that the so-called musical spark, in reality, does not give in the receiving circuit a low-frequency current of *a genuinely periodic nature and form*. As a matter of fact, the tone of the received note is with musical spark changed by acoustic resonance. In the case of the heterodyne reception of sustained waves, on the contrary, the received current at low frequency is really a periodic current in *which the same waveshape repeats itself* and actual acoustic resonance becomes possible. The use of acoustic resonance allows then the elimination of atmospherics of medium strength to a remarkable degree. I have built tuned low-frequency amplifiers (see my B.P. 130022) which have shown a noteworthy performance as far as elimination of atmospherics is concerned.

Unfortunately when the atmospherics become strong they themselves assume the same musical character as the reception and, generally speaking, no real help from acoustic resonance can then be obtained.

These results of experiments being well established, I believe that, from the theoretical point of view, Mr. Round makes the following mistakes.

(1) In modulated transmission with reception without heterodyne nothing but the atmospherics are received during the intervals. In the heterodyne reception of sustained waves, on the contrary, it is the *resultant* of the heterodyne and the atmospherics which is received and the two things are not, as Mr. Round thinks, exactly the same. The action of the heterodyne on the reception of the atmospherics is such that any oscillating discharge of long duration caused by an atmospheric produces the same note as the sending station itself. Undoubtedly the rapid variations of the intensity of these discharges which take place at audio frequencies and cause corresponding variations in the intensity of the musical note give the latter the characteristics of a noise similar to that produced by the atmospherics without heterodyne, but it is nevertheless true that the heterodyne gives to the atmospherics a musical character which, although not apparent, seriously diminishes the value of low-frequency tuning.

Here is a particularly impressive demonstration of the above reasoning.

A complete heterodyne reception being installed ready to receive a C.W. station and acoustic resonance at low frequency being provided, let us assume that the station is not sending and the atmospherics alone are being listened to. *Every time that the acoustic resonance is adjusted to the musical note that the station is supposed to give with the heterodyne, a remarkable strengthening of the atmospherics is observed.*

It is obvious that if the note were transmitted by the sending station as in the case of modulated transmission the above phenomenon could not occur.

(2) Regarding the claim of Mr. Round that there is no difference between the heterodyne reception and the reception with modulated transmission, the following reasoning shows that Mr. Round is misled by appearances.

When a C.W. station of frequency f_1 is received with a heterodyne of frequency f_2, the reception is naturally tuned to the frequency f_1. On the other hand a sending station transmitting two frequencies f_1 and f_2 which lie close together (modulated transmission) is received by tuning to the *average* frequency $\frac{f_1 + f_2}{2}$.

In the first case the oscillating discharges of the aerial of frequency f_1 can very well give the note $(f_1 - f_2)$ of the sending station.

In the second case the oscillating discharges of frequency $\frac{f_1 + f_2}{2}$ could only give a note of half the pitch $\frac{f_1 - f_2}{2}$.

In concluding, let me make the remark that while the modulation of the transmission for the purpose of reducing the atmospherics has been much discussed in the last few years (Round, Meissner, Lévy, Western Electric Company) the writer has been the first to recommend that this modulation be carried on at low frequency according to already known diagrams *and not at high or inaudible frequencies.* In addition when heterodyne reception with low-frequency tuning is used and the frequency of transmission is perfectly constant, it is preferable to tune the reception to a low pitch note as explained in my article.

MARIUS LATOUR.

Paris.

April 8th, 1921.