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McGILL UNIVERSITY PUBLICATIONS
SERIES X (PHYSICS) No. 29

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Reprinted from the Journal of The Franklin Institute
September, 1925

MONTREAL, 1925.

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ADVANCES IN PRACTICE.

THE use by Marconi of vertical reflecting wires, arranged in a parabola with the transmitting aerial in the focus line, has resulted in remarkable practical applications. In the case of a plain aerial, if 10,000 units are required to reach a given distance, then with a two-wave aperture parabolic reflector only 25 units are required, whereas with an eight-wave aperture only 1.56 units are required. Hence with power of 18 kw. on the oscillator valves and with a wave-length of 92 metres, large distances, such as from Cornwall to Buenos Aires, 5820 nautical miles, have been reached, and on this wave-length daylight signals have been reliable, and night signals stronger than were expected.

Another method which is now being employed is that of a network in a vertical plane resembling a gigantic tennis-net 3000 feet long and 300 feet high. L-shaped conductors on this net are insulated and tuned to the desired short wave-length. Behind this, at a distance of a quarter of a wave-length, is another plane network used as a reflector. By this method, instead of using lofty towers 820 feet high with 250 kw. on the aerial, involving the use of expensive insulators, it is sufficient to put about 25 kw. on the network in order to obtain equally good results, and the engineering problem is also much easier.

It is somewhat remarkable that experiments indicate that waves of a hundred metres give bad results during the daylight hours, whereas waves of thirty metres give good results by day, but bad by night. With an intermediate wave-length of about 45 metres, results are equally good both by day and by night, so that this wave-length is likely to be employed for long-distance signalling, as from Canada to Australia. It is noteworthy, too, that Macmillan in Alaska is to communicate next July with Schnell on the *Seattle*, U. S. Navy, in the antipodes, off Australia, with a wave-length selected as 20 metres. In fact, the day of the short wave-length has arrived!

* Communicated by the Author.

Experiments at Hendon, employing 700 watts with 4000 volts on the transmitters, have rendered good speech at 97 miles with a wave-length of 15 metres. Atmospherics are not troublesome, unless a thunder-storm is actually in sight, but trouble has arisen from the magnetos of automobiles emitting 15-metre waves which produce clicks in the receivers. Waves as short as 4 metres have also been tried.

At Inchkeith, in the Firth of Forth, two rotating parabolic reflectors have been mounted back to back on a vertical column with an aperture of 13 metres, which is about double the wave-length 6.3 metres. These reflectors revolve and give Morse signals for various compass bearings, so that a ship at sea is able to pick up its bearing from the land. It is probable that this method of signalling, by which a ship can obtain its own position from a revolving radiator on land, will be extended.

The amateurs have certainly developed with efficiency any bands of frequency assigned to them. It is not possible for them to use parabolic or plane reflectors, and so they have spread their radiations in all directions, frequently attaining success with remarkably low powers, for example, from England, to their antipodes in New Zealand with a quarter of a kilowatt, from Montreal to British Columbia, with 15 watts input and 5 watts output, and similarly from San Francisco to New Zealand. Best of all from Halifax to England with 2 watts!

Mr. J. Miller, of Montreal, signals to New Zealand with 100 watts and to England with anything from 30 to 110 watts.

He states that with the sun shining on his aerial he gets good results with 5-metre or 20-metre waves, but that the signals are poor in cloudy weather and fail entirely at night when he perforce lowers his frequency. There does not appear to be any known reason for this remarkable effect, which he states is a common enough experience. He states that 20-metre waves give him the best results by day. Miller states that with short waves, say 5 metres, there is frequently no reception within about 500 miles, but results are obtained at greater distances, as though the waves first mounted upwards and were then reflected or bent downwards.[1] Appleton makes similar statements.

Pittsburgh broadcasts both on 62 metres and on 309 metres,

[1] I learn that rays from Pittsburgh to Australia pass Fiji, but cannot be detected there. (See also the papers of Reinartz in *Q. S. T.*)

so that comparison can be readily made between these waves. The shorter wave (62 m.) conveys speech admirably at short distances, but the results are described as "mushy" at greater distances, at Montreal, for instance. Indeed some amateurs believe that the higher audio tones travel faster on the carrier wave than do the lower audio tones, a difficult matter to explain, if correct.

For transmission amateurs do not use the ground but a "counterpoise" or series of wires beneath the main aerial, the two sets being 60 and 20 feet above the ground for example. In other cases the aerial is vertical, ungrounded, with a coil in the middle coupled inductively or by capacitance with the transmission set. The skill and perseverance of amateurs is worthy of more recognition, and their results have great scientific interest.

ADVANCES IN THEORY.

The old question as to the method by which wireless waves travel round the earth has had much life given to it by a valuable discussion and theory due to Sir Joseph Larmor, published in the *Philosophical Magazine* for December, 1924.

Again, in the *Proceedings of the Physical Society of London* (February 15, 1925) there is a full summary of a joint meeting of the Physical Society of London and the Royal Meteorological Society. This summary should be read, because it throws much light on so many interesting and important topics. The speakers included Eccles, Chree, Appleton, C. T. R. Wilson, Simpson, Chapman and others.

A brief summary will be here given indicating the modern viewpoint.

In June, 1912, Eccles [2] first gave a theory of the Heaviside layer of ionized gas, highly conducting and supposed to be capable of reflecting electromagnetic waves in the higher atmosphere, while in the middle atmosphere the ionization is assumed to be sufficient to bend the rays round the earth. Eccles attributed the bending to the small oscillations given by the radio waves to molecular ions.

To-day Larmor assigns the bending to light ions, such as hydrogen ions, or to electrons, or to both.

Fifty miles (80 km.) up in the atmosphere the free path of

[2] *Proc. Roy. Soc.*, p. 86.

molecules between collisions is 2 cm., while the number of molecules per cm.^{3} is 10^{15}, as compared with 3×10^{19} near the earth.

Larmor shows that during the time when the light ions or electrons are moving quite unimpeded from one collision to the next, there is time for the wireless waves to set them into vibration with a not insignificant amplitude (which varies with the square of the wave-length). These oscillations constitute a current of a character quite similar to a Maxwellian displacement current. The true dielectric constant is decreased, and the velocity of the wireless wave is correspondingly increased.

Hence with correct adjustment of the transmitter the rays can be directed round the earth to distances such as 13,000 miles, travelling in their journey between the earth and the conducting layer about 50 miles above it. At the best an aerial can draw on this radiation over an area of the order of the square of the wave-length employed. There is sufficient energy for all receivers.

The dielectric constant, K, becomes the effective K' where

$$K' = K\left(1 - \frac{N^2 e\lambda^2}{\pi m}\right)$$

Here N is the number of electrons or light ions per cm.^{3}, e is the charge and m the mass of any one of them, while λ is as usual the wave-length.

Larmor shows that even *one* freely moving electron per cubic centimetre at the upper limit would suffice for the requisite bending round the earth, especially as he points out that free electrons can and do frequently pass through atoms without collision with the constituent parts of the atoms.

On the other hand, it appears that we must abandon the Heaviside layer as a reflector! Theory indicates that it would absorb and scatter and hence destroy wireless waves, rather than reflect them. Yet most practical radio experts find strong indications of reflected waves.[3]

Appleton suggests that the rays are bent rather than reflected by the Heaviside layer, so that we have a mirage rather than a reflector influence.

Chapman points out that he finds from magnetic results that the conductance of the upper layers is equivalent to a metre

[3] In a later letter to *Nature*, Larmor points out that with fairly abrupt transition to a well-ionized layer there may be reflection of wireless waves analogous to the reflection of light from metals.

thickness of copper over and around the earth. This layer is penetrated by short wave radiation such as light, but it would presumably not be penetrable by radio waves.

If radio waves go half round the earth with the velocity of light (c), then the upper part of the waves have a longer path to travel, and to keep up with the lower parts they must necessarily move faster than light. This at first appears disconcerting to the relativist! But the difficulty is capable of explanation.

ATMOSPHERICS.

C. E. P. Brooks has collected valuable statistics on thunder-storms. A single station reports on an average 16 thunder-storms a year over an area of about 200 square miles, so that the whole earth has about sixteen million thunder-storms a year, or 44,000 a day. If on the average they last for an hour, then there are always 1800 thunder-storms in being, and allowing 200 flashes per hour per thunder-storm, we find 360,000 flashes an hour, or 100 flashes a second over the whole earth.

These will be sufficiently numerous then to disturb the most enthusiastic radio fan! For example, around London for a radius of 1000 km. there will be about one flash a minute in winter and about a dozen a minute in summer.

South Africa and South America appear to be the places where the greatest number of thunder-storms occur.

It seems quite certain that lightning flashes do cause atmospherics, but other causes may exist. For example, C. T. R. Wilson points out that there may be silent but abrupt discharges between the Heaviside layer and the upper regions of a thunder-cloud.

Appleton and others have taken observations on atmospherics with the Western Electric cathode-ray oscillograph. The disturbances are of four types indicated by Figs. 1–4.

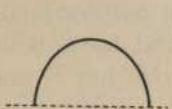
Fig. 1.

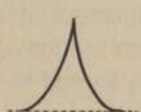
Fig. 2.

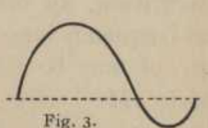
Fig. 3.

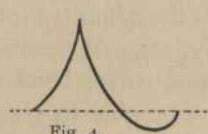
Fig. 4.

The periods of these oscillations are measurable in millionths of a second, or microseconds (μs), and occasionally in thousandths of a second, or milliseconds (ms.). The electric forces are not large, the main type being of the order of 1 volt for 8 metres, but at Khartoum as much as 250 volts has been received on the aerial, or 4.2 volts/metre.

An average lightning flash consists of from 3 to 6 discharges lasting each about 3 milliseconds with quiet intervals of a similar period intervening.

EXTINCTION OF SIGNALS.

Austen has accounted for the weakening of wireless waves with distance by an extinction factor $e^{\frac{-ar}{\sqrt{\lambda}}}$ involving the distance of propagation r, and (it will be noted) the square root of the wave-length. The constant a has a value of .28 for dry land or sand, and .0025 for water where r and λ are measured in kilometres. It is important to have a good conducting ground around the transmitting aerial so as to launch the radiation with an upright wave front.

Inasmuch as signals travel with less loss between flying aeroplanes than between ground stations, it appears that it may be desirable to launch waves tilted upwards from the ground.

ON WANDERING WAVES.

In addition to the Larmor bending effects due to light ions, it seems to have been proved that the earth's magnetic field, of the order of one-half a gauss, provided that ions or electrons are present, institutes a change of direction which will be least in the magnetic meridian and greatest for propagation at right angles to that direction.

Theory indicates that the plane of polarization may be rotated to an amount dependent on the electron density, the magnetic intensity and the frequency.

Hence we import into radio theory all the familiar peculiarities of double refracting crystals in physical optics, with rotation of the plane of polarization, an ordinary and an extraordinary ray, etc. At a critical frequency long waves may bend down, while short waves bend up. *A* may be able to signal to *B*, but *B* may not be able to signal to *A!*

We find here ample reasons for the violent errors in direction finding about the hour of sunset which are so troublesome in practice, and which were so obscure in theory. Nichols and Schelleng, of the Bell Telephone Company, have called attention to these explanations in an article to *Nature;*[4] but much material had already been published in the *Physical Society of London Report* (February 15, 1925).[5]

It is interesting to find the theories of atmospheric electricity, earth's magnetism, and wireless waves all intermingled so that an advance in any one of them is likely to throw light on the other two, and this fact suggests the desirability of bringing atmospheric electricity within the scope of the meteorological offices of all nations.

In conclusion, I point out with delight the truly international and coöperative character of the brotherhood of radio investigators. When this spirit pervades further the people, the politicians and the governments of the nations of the world, we may begin to think and work internationally, and so bring about an age of thoughtful adjustment of difficulties instead of blind prejudice leading to hatred, war, waste and the possible destruction of such civilization as man has so far managed to achieve.

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[4] March 7, 1925, pp. 334–335.

[5] They give a clear and forceful statement (pp. 215–234) in the *Bell System Tech. Jour.* for April, 1925.

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