CHAPTER XI

The Heaviside Layer

THE surprising fact that electric waves travel round the earth, instead of spreading out in straight lines like the rays of ordinary light, has set a problem to mathematicians which many have taken up and found to be of considerable difficulty. It is known that waves can be guided along conductors under certain conditions; and, in fact, that is how ordinary telegraph signals are conveyed, whether by land wire or by cable: they travel through the insulator, but are guided by the conductor.

Conductors are opaque to waves—they cannot be penetrated; at least, the better the conductor the more opaque it is. But a conductor can reflect waves. And if they establish a footing on its surface they can creep, or rather flash, along it with great ease, leaving a little energy behind them if the conductor is imperfect, and becoming thereby somewhat distorted, but travelling almost free from distortion if the conduction is nearly perfect.

One way, therefore, of treating the problem of long-distance transmission mathematically is

https://doi.org/10.1017/CBO9781139381093.013 Published online by Cambridge University Press

to imagine the earth a perfectly conducting sphere, and find out what would happen in that case. After solving this difficult problem, the data may then be modified so as to introduce a certain amount of resistance, making the earth an imperfectly conducting sphere, as if, for instance, it were totally covered by sea-water. A third attempt, hardly one tractable mathematically, can aim at distributing land and water into continents and oceans, and seeing what happens then. That, however, is one of the empirical problems that can only be approximated to.

Another plan is to treat the subject optically, not electrically at all, and to think of waves curling round an obstacle by what is called diffraction. The laws of diffraction for small obstacles are pretty well known; and if the earth could be treated as a small body in comparison to the size of the waves—that is, if the waves were as big as the sun or the solar system—then diffraction would be efficient, and there might be a focus or concentration of such waves at the Antipodes. But that is a quite different notion from anything appropriate to wireless telegraphy. Diffraction will not account for the curling round of ordinary ether waves. Nor is earth conduction very satisfactory.

And yet the waves do curl round, and easily reach America, whereas if they went in straight lines they would be going far overhead, even for that distance. And now Senatore Marconi appears to find that even short waves, or comparatively short waves, travel enormous distances under favourable conditions. What are those favourable conditions? If they were due to earth conduction, they would not be so likely to vary as they do. The fact that they are capricious and dependent on sunlight and other causes shows that the conditions must be partly regulated by the atmosphere.

And, as is well known, Mr. Oliver Heaviside attributed the curling-round of the waves to the influence of a good conducting layer in the atmosphere overhead, acting concurrently, perhaps, with the salt-water below, so that the waves were enclosed in a stratum between two conducting surfaces, the air effect being, on the whole, more efficient than the earth conduction.

Everyone who has worked with vacuum tubes with an air-pump knows that at a certain stage of exhaustion the residual air is conducting, or at least breaks down very easily, conveying a current and lighting up at very small voltage; whereas when the air is at high pressure, or very low pressure, great voltage is needed to drive a current through it; but at the best conducting vacuum, very small voltage suffices.

Now, as we ascend through the atmosphere we pass from ordinary atmospheric pressure to zero. Consequently a best conducting layer must exist. Yet a stratum of that kind is so gradual that it is unlikely to be able to serve as the layer postulated by Mr. Heaviside, even if it were sufficiently conducting. But it is well known that air can be made conducting in various ways; notably by X-rays, and even by ultra-violet light; also by combustion, as by flames; and by various kinds of physical or chemical action, even by splashing water.

These agents are said to ionize the air, that is, to eject electrons from atoms; so that electric charges are free in the air for a time, and are able to conduct, as they do in metals, where for another reason they are extremely free.

The chief ionizing factor in the atmosphere is probably the solar rays. What we get down here of sunshine has been filtered by the atmosphere. But the upper layers of the air have to stand a bombardment of the unfiltered sunlight. By ascending a very high mountain or going up in a balloon, we may experience the sunlight only partially filtered. The result is that we get first bronzed, and then blistered.

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There can be little doubt that the really unfiltered sunlight would be fatal both to animal and vegetable life.

The radiation from so extremely hot a body as the sun is of a very violent character, having all the deleterious qualities of X-rays, and others in addition. So unfiltered sunlight constitutes a powerful ionizing agent.

Also it appears that the sun itself shoots off free electrons, mingled probably with positive particles. These, according to Arrhenius, would be sorted out by the earth's magnetism, the positives falling mainly at the tropics, the negatives being deflected to the poles, where they give rise to auroræ ; the opposite charges ultimately recombining, with recognized atmospheric effects and earth currents and other disturbances.

Sunlight is one of the main causes, therefore, which may give us a fairly sharply bounded conducting stratum in the atmosphere, though it may be corrugated and otherwise distorted by heat effects. And this layer it is which has been treated as the main reflector, or whispering gallery, responsible for keeping the waves travelling round the curvature of the earth, and partially preventing their escape into space.

Dr. Eccles has dealt with the theory of an ionized atmosphere very thoroughly. And on the whole this Heaviside layer has been felt fairly competent for its work, though admittedly the whole subject demands extensive observation and record of experience before the theory can be considered in any respect complete. Like all meteorological phenomena it is complicated by a multitude of causes, and no one single theory can adequately cover the ground.

In one of the interesting and instructive wireless articles which Prof. Howe contributes to the *Electrician* once a month, he comments (in the issue of June 13, 1924, p. 720) on what he calls " the overworked Heaviside layer " in the upper atmosphere, and on the criticism of it by Prof. Guinchant, of Bordeaux.

This gentleman objects that the layer is not sufficiently conducting, for low E.M.F.s, unless it is ionized; and he claims that the sun cannot ionize it, for two reasons: first, because a constant supply of electrons would soon overcharge the earth and deplenish the sun, much as a thoroughly insulated filament in a valve could not continue to do its work properly; and, secondly, because ultra-violet light can only ionize things when it encounters dust or solid particles. But I suggest that Prof. Guinchant overlooks the exceedingly high frequency of some of the radiation likely to be emitted by a body at the temperature of the sun. Some of it would be X-rays, competent to ionize even oxygen atoms ; and, anyhow, there is no doubt that the upper atmosphere *is* ionized : the aurora is sufficient evidence of that.

The problem of the transmission of waves round the world is a most interesting and difficult one, and certainly the last word on it has not yet been said. But few acquainted with the facts can doubt that the atmosphere is largely responsible for the possibility. It must be the main deflector for world transmission. If it is ever found that short waves are able to go round as well as long ones—and some recent statements suggest that facts are trending in that direction—then the whole question —I do not say will have to be re-opened, for it has never been closed, but the whole question will enter on a new phase.

The way in which natural conditions seem to assist long-distance wireless communication, and, as it were, unexpectedly to lend a helping hand, is rather remarkable. It is generally said that the perfect adaptation of ways and means to ends which we frequently encounter in the operations and processes of live things must be due to their long-continued adaptation through the ages and survival of the fittest.

But that explanation cannot be applicable to a recent innovation like radiotelegraphy ;

https://doi.org/10.1017/CBO9781139381093.013 Published online by Cambridge University Press

and it is interesting to find in the earth's atmosphere a favourable agent which indirectly promotes radio communication, even at enormous distances, and thus lends itself to the convenience of man, although the inception and development of the process cannot have allowed any time for adaptation and survival.

Before closing this chapter I might try to give a notion of the latest ideas on this subject of curved wave transmission. The way in which an ionized layer in the upper atmosphere would behave, has now been elaborately examined mathematically both by Dr. Eccles and Sir Joseph Larmor. That the upper air is ionized by sunlight is certain: electrons are thrown off from the atoms under the influence of light, especially light of extremely small wave-length. Such electrons may attach themselves to atoms, and by their elastic connexion confer upon the ether extra elasticity. Or, if electrons are hollow, they may cause diminished density. In either case the velocity of light would be slightly increased, both in Eccles's theory and in Larmor's,—which are really much the same, when Eccles's later papers are taken into account. Thereby the upper portions of a wave will go quicker than the lower portions; and thus, instead of being

https://doi.org/10.1017/CBO9781139381093.013 Published online by Cambridge University Press

straight, their path will be curved, somewhat as waves of sound are curved by a wind which blows them along and blows the upper portion faster than the lower. One particular curvature would enable ether waves to get all round the earth ; and Larmor has told us the conditions under which that desirable curvature can occur. (*Phil. Mag.*, December, 1924.) Hence it may now be said that the propagation of radio waves to great distances, experimentally discovered by Senatore Marconi, has been properly accounted for, and, by help of the combined influence of atmospheric properties and solar radiation, has been explained.