CHAPTER X

Earth Transmission

IN the early days of Hertz waves—1888 to 1894—when we were engaged in demonstrating the reality of electrical oscillations in the ether, that is, in free space, we avoided earth transmission as being unfair and deceptive, suggesting the conclusion that the disturbance was being transmitted by the conducting power of the earth, rather than by the insulating power of the ether.

Thus, for instance, if a Hertz vibrator or a discharging Leyden jar was attached to the gas-pipes of a building, it was easy enough to get disturbances in neighbouring buildings, and to light the gas at a distant jet by turning it on and bringing a finger or piece of metal near it. It was possible also, and more interesting, to get sparks in unexpected places, as, for instance, between gas and water-taps which happened to be near each other in a basement, when the discharge circuit of a condenser was completely insulated in a room above—which is indeed a modification of the experiment that Joseph Henry conducted at

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Washington D.C. long ago, though at that date he could not know the meaning of it.

So long, therefore, as we were experimenting with wireless waves mainly for theoretical and, so to speak, optical purposes, verifying Clerk Maxwell's theory of light—reflecting, refracting, and polarizing the waves by suitable appliances, and seeing how far and by what means they could enter closed spaces—it was natural and proper to have the main oscillator insulated from the earth, and avoid anything that could be suspected in the direction of earth conduction.

But when Senatore Marconi, in 1896 and onwards, applied these waves to practical telegraphy, his object was to get the signals at a distance, no matter by what means they went: and he therefore naturally and properly employed earth conduction for all it was worth, making a good earth-connexion at both sending and receiving stations, so that the earth became part of the oscillator. Thus began the Marconi earthed aerial, which, as we all know, is very effective for big distances.

We were all fully aware that the effect of this would be to dichotomize the waves, which had been depicted diagrammatically by Heinrich Hertz, and to assist them to run along the surface of the ground so far as it was

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conducting. It was natural therefore to expect and to get better results over sea than over land.

So also if we wanted to get signals from a coherer inside a closed metallic chamber, we found we could do it by allowing some metallic conductor to enter that chamber, provided it was insulated from the chamber at its place of entry. The entry of a gas-pipe, for instance, into a metal-coated room, had the virtual effect of turning the room inside out, and of thus eliminating its screening property ; though without such introduced conductor a metallic enclosure was a complete stopper of ether waves. But we found that the merest chink, or even a bad join in the metal-coating of a chamber, allowed some of the waves to penetrate ; though a round hole was not equally effective, unless a bit of gutta-percha covered wire was put through the hole, so as to act as a sort of speaking-tube or conveyer of the waves into the interior.

We also suspected that any stray conductors, like wire fences or buried lodes or any other conducting material, would help to transmit the waves. And Dr. Alexander Muirhead applied to a cable company for permission to make connexion with the outer iron sheathing of a cable, in order to see whether the signals could not thus be transmitted with greater ease. The dislike of any responsible cable company to the idea of high voltages applied to any part of their cable, prevented this experiment; and good earth connexion was found sufficient without it.

That metallic conductors conveyed the waves was, however, well known; for the first evidence of the existence of such waves along wires was obtained by reflecting them so as to get nodes and loops, early in 1888 and even before the publication of Hertz's great discovery of their ready transmission by free space.

How far earth-conduction assisted, or would be likely to assist, the transmission of waves between a completely insulated transmitter to a completely insulated receiver, became an open question; and at Messrs. Muirhead's works many experiments were made of this kind. What we found was that the avoidance of earth connexion assisted the definiteness and purity of the waves, prolonging the oscillations and rendering very accurate tuning possible. We found, indeed, that earth connexion spoilt the tuning by damping the waves; and we therefore preferred to use an aerial consisting of two insulated capacity areas, one elevated as high as practicable, and the other suspended at a fair height above the earth. We found,

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indeed, that the best position for the lower capacity area was at such a height that the capacity of the whole was a minimum. If the lower area were put higher, it was brought too near the upper area. If it was put lower, it was brought too near the earth. We found a position at which the tuning was sharpest, and a record of these experiments was published by the Royal Society at a later date when they were fairly complete. (See *Proceedings of the Royal Society*, vol. 82, p. 227, 1908–9.)

It was found, however, that for practical purposes the use of the earth as the lower area was simpler in practice, and in some positions was inevitable; as, for instance, on board ship, where the sheathing of the ship made a perfect earth, and no lower area could be tolerated. It was found also that the lower area or balancing capacity was always rather a nuisance and an expense, and that even if it was constructed it was inconvenient unless buried. It was found also that the extra damping, though in itself to a certain extent objectionable, was not so deleterious as might have been expected, when a coil of considerable self-induction was employed; since the inductance of the circuit, by prolonging the waves, could partly overpower the damping effect of the earth.

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The thoroughness of earth-connexion, however, might vary in different localities. Some soils constitute a very bad conductor, others a good one. Wherever sea-water is available there is no question but that it is desirable to use it. For whether earth conduction assisted every kind of wave, even from insulated aerials, there was no doubt that it would assist when the earth was made part of the oscillating system. The only objection to it was that it was indefinite, and might have a high damping resistance. Even now it would be well to use a lower capacity area for any experiments involving really precise tuning. But for practical purposes all that was necessary was to get sufficient tuning, and to reach the greatest distance possible.

The whole subject is summarized in Prof. Fleming's treatise on "The Principles of Electrical Wave Telegraphy and Telephony" (Chap. VIII in the second edition, probably in the first edition also). And the experiments of Zenneck on different kinds of earth—that is, on the effective different kinds of soil—is there quoted and elaborated, with a citation also of further experiments by Brylinski (p. 743). The usual diagram of the dichotomized Hertzian waves is given on p. 408 in Chap. V, Section 2, where the earth is considered as a perfect conductor acting as a mirror to the upper capacity area, and as if the lower area were an equal distance below the surface. A similar discussion will be found in Pierce's "Principles of Wireless Telegraphy," Chap. XV.

How far such a condition really obtains in practice must depend on the kind of earth available; and the distortion which the waves inevitably undergo by travelling over poor conducting soil must be learned from the experiments of Zenneck and others above referred to. (See, for instance, p. 736 in Section 14 of Fleming's treatise, Chap. VIII.)

But I see in the *Electrician* for August 11th, 1924, p. 148, that Prof. Elihu Thomson claims that this earth transmission is the really effective way in which the waves are conveyed to great distances, and are by this means enabled to go round the curvature of the earth, and reach even the Antipodes. So he concludes that any upper conducting layer in the higher parts of the atmosphere is unnecessary to explain the transmission, and that the existence of such a reflecting layer has become a superstition.

It is difficult to decide this by experiment, for we cannot get away from the upper regions of the atmosphere and determine how effective the sea alone would be without what has been called "the Heaviside layer" in the atmosphere. But it is plain that there must be a best conducting layer in the air; since the density of the air varies, as you ascend, from its ordinary value down to absolute vacuum, and it is known that during the exhaustion of vacuum tubes, when the pressure is a few millimetres of mercury, the residual air does conduct to a degree almost comparable with the conducting power of water. It is further plain that if ether waves are confined between two strata, both fairly conducting, one above and one below, they will be kept from escaping in all directions, and will spread out in only two dimensions, thus surely economizing their power.

It may be argued that the conducting layer in the upper air is too gradual to give sharp reflection; that is to say, that the thickness of this layer is greater than any probable wavelength, and hence that they might succeed in penetrating it. I doubt whether this is the contention. I believe that the contention of Prof. Elihu Thomson is rather that the layer is likely to be too irregular, too corrugated and uneven, to act as anything like a reasonably good mirror, even for big waves.

I should suppose that in the daytime, when the air is subject to all manner of vertical currents from the heat of the sun, such corrugations might very well occur; but that during the night, even if there were a wind below, the upper regions of the air, with their high kinetic viscosity, might be trusted to preserve a fairly even surface. And anyhow the demonstration, by Signor Marconi's large scale experiments, of the conspicuous influence of sunlight in spoiling transmission is not readily explicable unless the atmosphere has something to do with it. If transmission depends only on earth conduction—as Prof. Elihu Thomson seems to think—one would expect signals to be as good in the daytime as in the night.

Hence, on the whole, I think facts point to a real influence of the upper atmosphere on transmission; and whether the part played by the atmosphere can be dissected out from the part played by the earth or sea, may have to be settled by the mathematicians. And from different points of view the opinions of such authorities as Prof. Eccles, Prof. McDonald, Prof. Watson, and Dr. Chree, as well as Mr. Heaviside himself, may have to be ascertained before the question can be considered settled. I do not suppose that Prof. Elihu Thomson considers that he has settled the question, but rather that he has raised it in a more acute form, and has reopened it in all its bearings.

I have indicated sufficiently that, at the present stage, and on merely general grounds, I have nothing dogmatic to say about it, but anyone can be impressed :—

(*a*) With the fact that a conducting layer in the upper air is inevitable.

(*b*) That such a layer, if effective, would be a great assistance in very long distance transmission.

(*c*) That, without it, the deleterious influence of sunlight seems rather inexplicable.

Finally, Prof. Elihu Thomson writes as if there had been undue scepticism concerning Senatore Marconi's great achievement of first getting wireless signals across the Atlantic. I know of no undue or improper scepticism about it. A hope was expressed, by myself among others, in a congratulatory letter to the Press, that further experience would confirm the result (as it conspicuously has), but caution in accepting a newspaper report of a remarkable achievement is not unprecedented, and hasty enthusiastic congratulation on the strength of such reports has not always been justified.

The transmission of ether waves round the earth is a fact of such practical and theoretical interest and importance that it has inevitably involved a good deal of discussion, and it may be well to continue to indicate some of the changes of opinion that have occurred.

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