The Speed of Radio Waves

A New Article by Sir Oliver Lodge

By the courtesy of "Modern Wireless," we are able to republish this fascinating article by Sir Oliver Lodge, in which he gives readers a peep behind the scenes in the Cavendish Laboratory, which is world-famed for the scientific discoveries made there. He tells just how, by means of photographic plates, and in collaboration with Sir Richard Glazebrook, he was able experimentally to verify an important theory about the speed of radio waves.

NOWADAYS it is well known—though it was by no means well known when early experiments were conducted—that whenever electric oscillations occur the ether is perturbed, and that electro-magnetic waves are produced, which are supposed to travel out with the velocity of light.

This fact was predicted by G. F. FitzGerald mathematically on the basis of Clerk Maxwell's theory, and was experimentally verified by Hertz, and indeed by the writer also. But Hertz did it better and more completely, and moreover gave a very complete explanation of the detailed process by which the waves were emitted.

The discovery was made public by FitzGerald at the British Association meeting in Bath in the year 1888, before anything like wireless communication was thought of, and before there was any proper means of detecting the waves.

Hertz could only detect them by the surgings which they produced in properly attuned receiving circuits, those surgings being demonstrated by the overflow or spark which they caused. The surprising thing was that the waves were strong enough to produce sparks, even when the receiver was separated by a fair distance from the emitter. And thus Clerk Mawell's theory was qualitatively verified.

Theory stated that if any such electro-magnetic waves were produced they must travel through space with the velocity of light; and it is now universally assumed that wireless waves do travel with the velocity of light.

But even advanced experimenters may sometimes wonder whether this is exactly true, and whether any experimental proof has been given that the velocity of electric waves, of the considerable length used in wireless practice, really do travel at the same rate as the utterly minute waves which are able to affect the eye.

Velocity never Properly Measured.

THE velocity of light has been measured with great accuracy; but I am not aware that the velocity of wireless waves has ever been really measured at all. Being waves in the ether, it is natural to assume that, whether long or short, they all go at the same rate, just as sound waves do in air. The rate of transmission of bass notes and treble notes must be the same, otherwise, as Sir Isaac Newton said, we could not listen to the music of a band at a distance. There would be hopeless confusion if the notes travelled at different rates.

Obtaining Proof.

STILL we ought not to be content with the mere assumption that the same will be true for ether waves, and we may properly ask what proof has been given that electric oscillations of a few hundred or a few thousand a second emit waves which travel at the same speed as those of optical frequency, which in the case of yellow light are 500 million-million per second, and for all colours have to be expressed in hundreds of millions of millions.

The proof was really given by the present writer and Sir Richard Glazebrook working in collaboration in the Cavendish Laboratory in the last century. The method was to generate oscillations with high voltage, such as would cause sparks in a circuit containing a great capacity, made of interleaved glass plates and tinfoil, and a great coil of wire of about four henries inductance.

The rate of oscillation could be calculated for such a circuit on Maxwell's principles, in accordance with the theory first formulated by Lord Kelvin so long ago as the year 1853. He it was that worked out the rate of oscillation as dependent on capacity and inductance; though the term "inductance" was never then used; it was invented later.

Kelvin (then Professor William Thomson) called the one "electrostatic capacity," and the other "electro-dynamic capacity." That which he called electro-dynamic capacity was afterwards called self-induction by Clerk Maxwell, and much later was called inductance by Heaviside.

It is a magnetic phenomenon, due to the magnetic qualities of a current, as opposed to the purely electric phenomenon of charge. The oscillations are due to the interaction of magnetism and electricity; and so are the waves which Hertz found were emitted by the oscillations. Hence the waves are called electro-magnetic. Linear aerials collect the one form of oscillation. Frame aerials collect the other—the magnetic—kind of oscillation.

An Ingenious Method.

BUT although the complete theory had been given, there had been no verification. The rate of oscillation had been calculated, but not observed. Glazebrook and I proceeded to observe it, on the supposition that the velocity of light was involved. To do this we photographed the spark on a rapidly revolving photographic plate. The plate revolved in its own plane at a carefully measured rate of about 60 revolutions per second.

The spark was focussed on the plate, not at the middle but near the edge, so that if it were drawn out it would form a circular band instead of a sharp line: and if the spark were an oscillating one the band would be beaded, that is to say, would consist of smears of light separated by minute intervals of darkness.

The plate so obtained when developed could be subsequently micrometrically examined and measured; and from the recorded image of the oscillations, knowing the rate of revolution of the plate, the rate of vibration could be accurately checked. The whole investigation is published in a volume of contributions by a number of different writers, as a Memorial to Sir George Stokes, one of the leading mathematical physicists of the last century—the teacher one might say of both Kelvin and Maxwell, as well as of the rest of the smaller fry.

Maxwell's Theory Proved.

THE result may be expressed thus: Lay off a length corresponding to the magnetic units of inductance in the coil employed; for on the magnetic system of measure inductance is a length. End to end with this line lay off another length as a continuation of the first, to correspond with the electric measure of the capacity of the condenser employed; for on the electric system of units capacity is a length.

Having those two lengths end to end, draw a semi-circle upon them; so that the two lengths together form a diameter. Then from the junction of the two lengths draw a perpendicular to meet the semi-circle. Measure the length of that perpendicular. With that length as radius let a wheel be constructed, or rather imagine to be constructed, with that length as any one of the spokes. In other words, take a wheel with that length as radius.

We now suppose that wheels to be employed like the wheel of a locomotive running along a line of rails, or on a flat surface, so that its rate of revolution shall correspond with the observed rate of oscillation as measured from the spark record on the photographic plate.

Maxwell's theory says that the rate at which that wheel would travel along as it rolls like a coach wheel would be the velocity of the waves emitted. The size of the wheel was known, the rate of revolution was known—both known from the conditions of the circuit.

The question then is, at what rate that wheel would advance; for that would be the velocity of the waves. Was it the velocity of light? It was.

What we actually did was to assume that it would travel forward with the velocity of light, and on that supposition calculated how fast a wheel of that size would have to revolve. Did the rate of revolution correspond exactly with the rate of electric oscillation?

Exact Correspondence Achieved.

THE answer given by experiment, that is, by measuring up a great number of the spark records on a number of revolving plates, was that it did correspond. The correspondence was exact: the theory was verified; the proof was established that electric waves of great length, corresponding to comparatively slow oscillations, travelled at precisely the same rate as the short waves that affect the eye. In other words, that the velocity of the waves used in wireless telegraphy, and the velocity of waves used in optics, whose speed had been actually measured, were identical.

The speed of ether waves is independent of the size of those waves, just as the speed of sound waves is independent. The ether transmits waves at one rate, and at one rate only, wherever it is free and not incommoded by matter, and not perturbed by other disturbances, such as the ionised air which occurs in the upper regions of the atmosphere.

Ionisation Complications.

WHEN space is not free, but is electrified, further complications occur, which (as everyone knows) have been worked out by the genius of Dr. Eccles and Sir Joseph Larmor; who showed that ionisation complications in the upper atmosphere enable the waves to travel round the earth in surprising fashion. The fact that they do so was first experimentally established or ascertained on a large scale by Marconi and his co-workers.