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A SHORT LECTURE ON WIRELESS TELEGRAPHY

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The Art of Wireless Telegraphy was, briefly, the art of setting up controlled disturbances in the ether of space, and detecting them at any desired point.

Although Mr. Marconi's name was, in the popular mind, associated with the development of this art to the exclusion of any other, it was a fact that its present position had been founded and built up on the work of many earlier workers.

Men with the historic names of Oersted, Faraday, Clerk Maxwell, Hertz, Sir William Thompson and others also had contributed to its foundations, but it was left to the genius of Marconi to show how a commercially effective edifice might be built thereon.

He did not wish to suggest for a moment that Marconi was merely a clever collator of other men's work.

An enormous amount of original work stood to his credit on the purely scientific side, and if his reward had been great, so indeed had been his deserts.

In 1865 Clerk Maxwell predicted from mathematical reasoning based on some of Faraday's experiments that variable currents in a conductor gave rise to electric waves in space, that these waves travelled with the velocity of light, and that indeed, light itself would be found to be a variety of such waves characterised by very short wave length.

Twenty-three years passed before the confirmation of this theory became a fact, when, at Karlsruhe, in 1888, Heinrich Hertz not only produced electric waves in space at will, but measured their wave-length, and showed that they could, by suitable means, be reflected and refracted as could light, and that as their wave-length shortened, so they showed properties more and more similar to those of light.

Now, as to the method to be employed to start these electro-magnetic waves in space:

If into a smooth sheet of water they were to drop a pebble, at once a disturbance was started by which the surface of the water was broken up into a series of rings, each representing the crest or hollow of a wave running out with defined velocity from the centre of disturbance.

If the sheet of water was large, or the original disturbance small, these rings would run on and on, the amplitude of each wave getting smaller, until they no longer perceptibly disturbed the level surface of the water, and could be said to have died out.

If during their passage these rings were to pass some light floating object, such as a small cork float, this would rise and fall vertically as each crest and hollow passed it; if they chose to imagine some kind of recording gear attached to the cork they should get a record of the passage of the wave—in other word, a detector of water waves.

What was the equivalent to our imaginary stone when they came to the practical business of starting off their electro-magnetic waves in space?

So far, the disruptive discharge of a condenser had been the usual method employed, though there were not wanting signs to which he hoped to refer later, that more economical methods might come about before long.

When a condenser was charged by being connected to some source of high tension current, such as a transformer or induction coil, a condition of electric strain was set up in the dielectric separating its plates. This strain, or to coin a word, electric "stretchibility," had its mechanical equivalent in the storing of energy in a stretched spring. When the jar was discharged this strain was relieved.

If the strain was relieved suddenly it was found that the analogy of the strained spring still held good, and that the charge, instead of passing from one plate to the other, and merely establishing equilibrium, had, as it were, overshot its mark and surged to and fro between the coatings of the jar, each time losing something of its energy, until at last equilibrium was really established, the dielectric was relieved of all strain, and the jar was discharged.

If the discharge of the jar was allowed to take place between some sort of spark gap interposed in the circuit connecting the inner and outer coatings of the condenser, the energy of the moving charge became very apparent.

A very good mechanical analogy of the surgings to and fro that go on when a condenser was allowed to discharge suddenly, could be obtained by imagining a U tube with one leg full of water, the other empty, and furnished in its bend with a stop-cock of large bore. They might say that it was positively charged in one leg and negatively in the other.

If the cock was now suddenly opened, the water in the filled leg would rush violently into the empty leg, but would overshoot by a long way the point at which, after several surgings to and fro, the water would settle down in both legs.

They would note that in describing the oscillating discharge of a condenser he had used the word "suddenly." If the tap in the U tube was opened very slowly, or only partially, they should get the mechanical equivalent of resistance in the discharging circuit of their jar, and the condenser discharge might then be unidirectional and not oscillate at all, merely flowing slowly until equilibrium was established. It was therefore very important in all circuits where they required the full benefit of the to and fro surgings of the discharging condenser, to keep the resistance of the discharging pathway as low as possible. This was usually done by providing ribbon conductors of large surface, or stranded conductors made up of a very large number of small insulated wires, either type of conductor offering a large surface to the rapidly oscillating currents of the condenser discharge.

There were two qualities in our jar circuit on which they must depend to secure oscillations of the discharging current: one was its capacity for storing energy, or electrical springiness, which they could control by regulating the size of their plates or coating, or by regulating the thickness or material of their separating dielectric material. It was usually designated by the symbol C. —standing for capacity—and was usually expressed in microfarads. The other quality was that of electrical inertia or inductance, the conservative quality which hated changes—which, being at rest, hated being moved, and having been induced to move, hated being stopped, and tried to go on.

It was the electrical equivalent of the mechanical inertia of matter, and was dependent on the length of the discharging circuit, and also on its shape. It was usually designated by the symbol L, and expressed in centimetres.

At the risk of being tedious on this part of his subject he would ask their attention for a moment to a mechanical model of an oscillating circuit: spring or capacity variable—weight or inertia variable—consequently oscillation period variable. The less friction of guides (equivalent to electrical resistance) the longer the oscillations maintained.

If they multiplied together the capacity of a circuit in microfarads and its inductance in centimetres, and took the root of the product, they got a quantity which Professor Fleming called the oscillation constant of that circuit.

It was obvious that there might be many circuits differing widely in their constituents of capacity and inductance which might yet have the same product of these quantities, and therefore have the same oscillation constants, and this flexibility was most useful when it came to designing circuits which had to absorb given power and yet produce given oscillations.

By varying one or both of the two important factors of an oscillating circuit the rate of the oscillations could be regulated to any frequency required, and it would be recognised that this was a necessity if they were to be able to produce in the ether waves of predetermined length. The rate of travel of an electrical disturbance in the ether had already been referred to as being the same as the velocity of light, viz., 300 million metres a second. If their condenser circuit then was arranged to oscillate once a second the wave length they should excite in the surrounding ether would be 300 million metres from crest to crest. If, on the other hand, they arranged for oscillations at the rate of 300 million per second, their resulting wave would be one metre from crest to crest. If they arranged for a frequency of 1,000,000 per second, they got a wave of 300 metres, and the commercial wave of 600 metres, with which most of the ship work was carried on, was obviously associated with a frequency of 500,000 a second.

Now, so far, although they had seen something of the means taken to store their initial energy and release it at a given rate, they had not touched on the important point of how it might be induced to travel far from its originating station.

In a closed condenser circuit such as he had described, there was very little radiation. The plates were close together, and the strain lines between the plates stretched out into space, but for a very small distance. Consequently they nearly all collapsed straight upon the plates when the condenser was discharged, and radiation was practically nil. The circuit was a persistent oscillator, but a poor radiator, and what they wanted was a circuit that not only oscillated but allowed the energy of its oscillations to leave it and travel away on their errand.

The arrangement of such a circuit was a very difficult problem, as the qualities required were diametrically opposed. A continuous oscillator could radiate well, and a circuit that radiated well would not oscillate persistently. No less an authority than Sir Oliver Lodge declared the problem insoluble, and his earlier patents in wireless matters disclosed arrangements which sought by compromise to give his circuits some of each of the desired qualities.

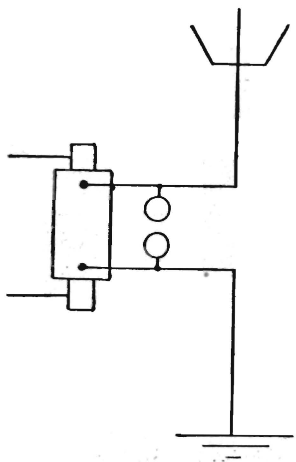

Fig. 1.

An arrangement of Marconi's, employed quite early, was shown in Fig. 1. A coil was shown raising the potential of an insulated air wire system until such a pressure was reached as broke down the air gap between the spark gap and discharged the air wire to earth.

Incidentally this diagram illustrated a very important improvement wholly Marconi's, viz., earthing one side of his spark gap. The moment he effected this improved arrangement the distance over which he could transmit became enormously increased. Prior to that time his experiments were carried on with the air wire only, the earth circuit being omitted, and his signalling distance was counted by fractions of a mile.

They might wonder at first sight what this diagram had to do with the condenser circuit concerning which he had said so much, but a little consideration would show that they had here only a special case of the condenser circuit.

The earth was one plate of the condenser, the branched top of the antenna, or air wire, was the other plate; the long air wire and the earth lead was the discharge circuit; and the familiar spark gap played the part of discharger as before.

They had therefore a system with definite capacity for energy storage, although very small and definite inertia or inductance due to the length of conductor. If they went on pumping energy into this system by means of their coil, they at length reached a point when the potential to which they had raised the system was sufficient to break down the air gap between the spark balls and a discharge took place across the gap. True to the case they had already examined, this discharge was oscillatory, charging the air wire first in one sense, and then in the opposite with great rapidity, the rapidity nevertheless depending, as they had already seen, on the qualities of capacity and inductance possessed by the whole vibrating system.

In other words, they had twanged the system, and it responded with a note characteristic of its electrical qualities.

They might ask why did the charged air wire discharge across the gap instead of through the secondary of the coil by which it was in metallic connection with earth?

The reply was that the inductance of the secondary was so high that the rapidly oscillating currents were wholly choked back and forced across the spark gap instead of traversing the secondary of the coil.

The general arrangement indicated was known as "Plain Aerial," and represented the emergency circuit carried on all Marconi-fitted boats to-day. Except as an emergency arrangement, its use was strictly forbidden by international agreement, for reasons which he would point out later.

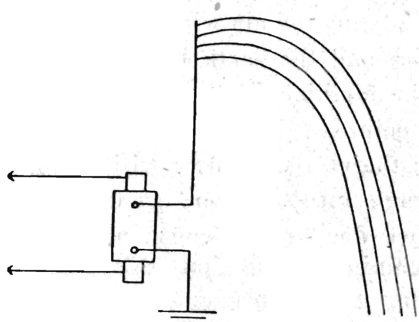

Fig. 2.

In Fig. 2 was shown a diagram in which an endeavour was made to show how the strain lines might be imagined to extend from the elevated portion of the air wire through the air dielectric to the other plate of the condenser or earth.

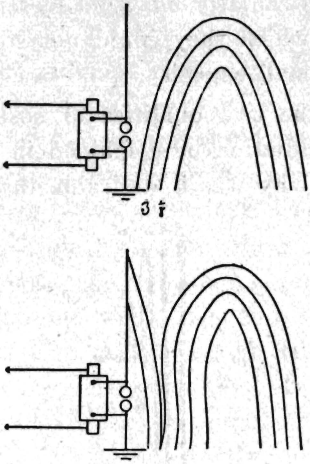

Fig. 3.

In Fig. 3 was shown what might be imagined to go on when the gap broke down and the lines of force began to collapse on to the air wire. Some did collapse, but the outer lines of strain had not time to get home, so to speak, before they were met with fresh strain lines developing from the air wire, due to the recharge of the aerial, and were actually pushed off into space to travel outward as closed loops of electro-magnetic energy, at a speed equal to that of light, and of a length governed by the frequency of the oscillating system of the air wire.

Now in the form of aerial they had imagined the capacity was very small, and insulation difficulties precluded the raising of the potential beyond a certain point. The opposite plates of the condenser were widely separated, and the strain lines between them stretched out far into space; and for this reason the system got rid of its stored energy very quickly, and was called a good radiator of energy. They had seen their closed condenser circuit, which was a good oscillator but a poor radiator; then they had a good radiator but a poor oscillator, and moreover, one into which they could not store much energy because of its small capacity.

How could the two qualities of sustained oscillation and effective radiation be combined in one transmitting appliance, and why was it desirable that they should be so combined?

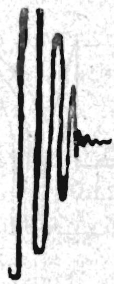

Fig. 4.

Let them examine the diagram in Fig. 4 of a sharply-damped wave, such as their plain air wire gives off if left to itself. So rapid was the dissipation of its small energy storage that it gave little more than one good swing—a kind of electrical pistol shot or whip crack, in fact. Now this kind of disturbance (although much good work was done with it in the early days when stations were few and far apart) was not permissible now except under emergency conditions.

If they were to fire a pistol in a room in which was a piano, the disturbance would be aperiodic, and all the strings would respond more or less. But one string only would respond to the pure sustained musical note of a violin string, viz., the one which, if struck, would itself emit the violin note.

Here they had a crude illustration of the undesirability of practically aperiodic vibrations such as their plain air wire system would give them. They should find all detectors more or less affected by the discharge, and chaos would be the result.

When it was useful, however, was in emergency when they wanted to make known their desperate need to everyone within hearing, no matter what wave their instrument might be adjusted to receive. Then the more that heard them the better, and they were very glad of a sharply damped aperiodic wave to shout with.

It was found that if two electrical circuits were alike as to their natural time period of vibration (that was if the product of their capacity and inductance be the same) that the second circuit would respond strongly to the first, although the first might be vibrating with comparatively little energy loss per swing.

A series of small pats was administered to the second circuit, which being timed at exactly the right instant, became cumulative in their effect on the second circuit, and if continued long enough would set it vibrating violently. Such a condition between two circuits was known as "resonance," from its similarity to the phenomenon of acoustic resonance of two strings or chambers tuned to the same vibration period.

If then they could arrange for their air wire system instead of emitting a series of explosions of no particular periodicity, to emit a succession of waves which only slowly lost their amplitude and died out, they should have the means of administering these little accurately-timed pats or impulses to a sympathetically adjusted circuit, and it was evident that a long continued wave of slight decrement or damping was what they wanted from their transmitter. Let them see how it had become possible to combine the persistently oscillating condenser circuit with the rapidly radiating air wire circuit. And here they broke most interesting ground.

It was Marconi's genius that devised the arrangement shown in Fig. 5, in which an oscillatory condenser circuit was coupled electro-magnetically with the air wire system.

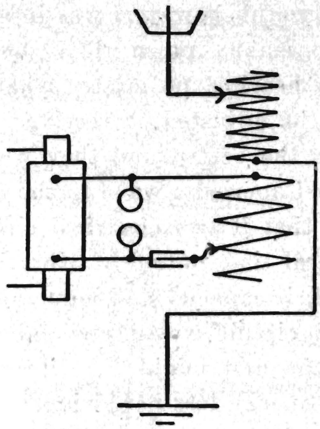

Fig. 5.

This was the subject of the famous 7777 patent of 1900 which was upheld in a great judgment by Mr. Justice Parker, when Marconi brought a suit against the British Radio Co. in London, and settled for ever his claims in this direction.

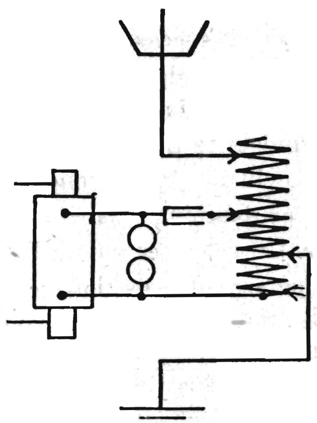

Fig. 6.