The Birth of the ANTENNA

by Greg Grant

Last year, 1995, marked the centenary of the antenna, a device so universal and indeed, crucial to our world, as to need almost no introduction. Yet, it was neither discovered nor developed, but arrived at accidentally by three men. One was a research physicist; one a lecturer at a naval college and the third, a young amateur experimenter with a wealthy father and indulgent mother. The physicist would be celebrated in a practical, if esoteric, way; the lecturer hardly at all and the experimenter positively showered with awards and distinctions. Indeed, even his death would engender a unique tribute.

In 1387, Heinrich Hertz, Professor of Physics at Karlsruhe, took the advice of his mentor, Hermann, Baron von Helmholtz, and set out to win the prize offered by the Berlin Academy for the first experiment that would demonstrate the existence of the electromagnetic waves predicted by James Clerk Maxwell.

Maxwell had put forward his theories as early as 1865, in a now-classic paper called 'A Dynamical Theory of the Electromagnetic Field'. It took some years for the theory and its associated equations to be accepted, and the first breakthrough came with Hertz's generation of electromagnetic waves, which he announced in the journal 'Annalen Der Physik' in 1888.

The equipment Hertz used is shown in Figure 1. His antenna was the first true resonator and was based on a disembowled Leyden Jar, that earliest of all electronic components aside that is, from pieces of fur and amber. The inner and outer foils of this early capacitor became the two arms of a dipole, separated by the Spark Gap. Obviously, this arrangement had both inductance and capacitance and so was a resonant circuit, which meant that if it was energised sufficiently to enable sparks to cross the gap, it would radiate at a collection of frequencies determined by the capacitance and inductance. The energising mechanism was a Ruhmkorff Coil, called after its creator, the German physicist, Daniel Ruhmkorff.

It was effectively a step-up transformer incorporating a magnetic interrupter, which produced spark discharges. Hertz's system, therefore, constituted the earliest form of radio transmitter, the Spark Gap.

For reception, Hertz used Knochenhaur Coils, flat loops of metal strip, the turns insulated by sealing wax and with a spark gap on each coil, as shown in Figure 2. This receiving loop had a radius of 35cm, which was found by experiment to be the proper size to be in resonance with the oscillator.

It was with these arrangements that Hertz established that electromagnetic waves existed and could also be bent and reflected. Hertz also, of course, modified this equipment a number of times in the course of his experiments and the frequencies at which he operated have been estimated to be anywhere between 50 and 500MHz, the present-day Very High Frequency (VHF) and Ultra High Frequency (UHF) bands. Shortly, however, what had come to be known as Hertz resonators were '. . . superseded by Coherers of various patterns'.

The coherer (a number of which are illustrated in Figures 3a to 3d) was basically a switch whose normal condition was off. when a voltage above a certain threshold level was applied, however, it activated, staying in this condition until tapped, or nudged physically.

The principle behind it had been stumbled across in 1879 by the Anglo-American physicist, David Hughes. He had noticed that when a Ruhmkorff Coil was operated close to a microphone-telephone circuit, the microphone resistance changed and sounds were heard in the telephone earpiece. Hughes took the view that the coil's electromagnetic discharge was inducing a reaction in the microphone's carbon powder, but friends persuaded him he was mistaken. Consequently, the coherer was later re-invented, as it were, by Eduoard Branly, professor of physics at the Catholic University of Paris. He published his findings in French in 1890, and they first appeared in English in the following year in the journal 'Electrician'.

The Branly design set the standard for almost all subsequent coherers. It was a glass tube containing loosely packed iron filings with connectors at either end. Not the least of the ironies concerning this would-be antenna, was that its inventor had no real idea as to why his device functioned as it did!

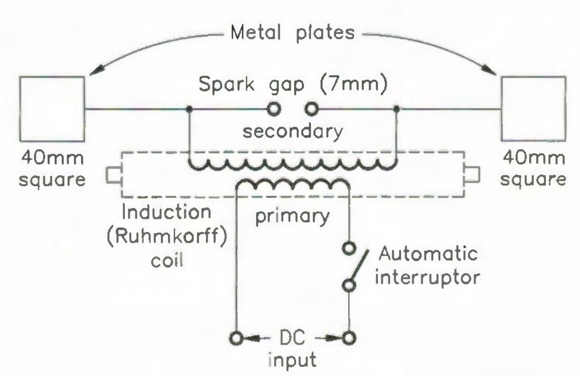

Figure 1. Heinrich Hertz's original equipment of 1887.

Figure 2. Hertz's receiving antenna – a Knochenhaur Coil.

Figure 3a. Branly's original coherer, 1890.

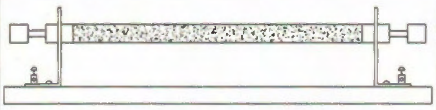

Figure 3b. Lodge's coherer of 1894.

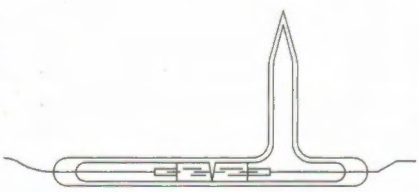

Figure 3c. Marconi's coherer of 1895.

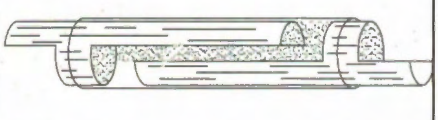

Figure 3d. Popov's coherer of 1895.

Branly, however, was not alone in discovering some of the odd properties of metal filings. In Britain, Oliver Lodge also invented a similar device. In fact, he was the first scientist or engineer to term this switch a coherer, thus indicating that he at least understood how it functioned. Lodge has a unique place in the development of communications engineering, not least, for his belief that the selective response of one individual receiver to an equally individual transmitter – what we, today, would term simplex operation – was crucial to ANY progress towards a communicative system, and particularly one based on what was still referred to as Hertzian waves.

A prolific inventor and component developer, two of Lodge's patents had important implications '. . . in particular, for the design of antennas and for the techniques of coupling electrical oscillations into and out of the antenna'. In fact, by 1892, thanks in large measure to Lodge, all the elements of an electromagnetic communications system were to hand, including the unearthed dipole and the Branly-Lodge coherer. In 1894, he gave a lecture entitled 'The Work of Hertz', which was read and admired by a Russian physicist and naval college lecturer called Alexander Popov.

In it, Lodge had outlined his experiments with a coherer. Popov repeated this experiment and, early in 1895, began investigating both the coherer and metallic powders. His receiver is shown in Figure 4. The coherer has a rubber ring around it for protection from the bell hammer. It is connected to a 4·5V battery whose current I flows through the coherer and the winding of relay RI, although it is not powerful enough to activate the armature (a).

When an electromagnetic wave strikes the coherer, however, the resistance of the powder within drops, current increases and (a) closes. This completes the circuit at z and activates the bell. When the tube is tapped, its resistance increases and the relay opens the bell circuit.

In the course of his experiments, Popov discovered that if he connected a 2·5m long wire to either points X or Y, the receiver picked up signals from a Hertzian vibrator, whose spark gap was lying in oil. He also noticed that when one side of the coherer was connected to a lightning rod and the other to earth, his receiver picked up atmospheric disturbances even when they occurred at a considerable distance. This led him to believe that his equipment could be used for over-the-horizon signalling. Popov, of course, was not alone in experimenting with Hertzian waves.

At the same time, a young Italian-Irish experimenter was also endeavouring to extend the infant technology. His abiding pre-occupation was distance. In fact, it would not be at all inaccurate to say he was obsessed with it. Guglielmo Marconi was conducting his experiments in the garden of the family home, the villa Grifone, and they were far from successful. Indeed, he had '. . . already tried to make his antenna radiate more powerfully by attaching metal plates to the arms. He had also tried raising it higher above the ground'.

This, of course, brought him a further problem; the inconvenience of having both the spark gap and the coherer out of reach for adjustment.

In early 1895, however '. . . while using slabs of sheet iron to increase the transmitter spark's wavelength, he placed one on the ground and held the other in the air. This, in effect the first aerial, produced a large increase in the signal strength and in the range – from about 100 metres to 1 kilometre'. The equipment he used is shown in Figure 5.

He had also adopted a similar arrangement at the receiver, which meant that both the transmitter spark gap and the receiver coherer were now at ground level and therefore, easily adjustable.

What Marconi had done, of course, was use the Earth as one of the dipole arms. It was this arrangement which, at last, gave him the distance he craved. In fact, it would be fair to say that this was the antenna Marconi used for the rest of his life, in one form or another.

He used it in his trials between Dover and Wimereau in 1898, and again in Newfoundland in 1901. He was not the first to employ this type of antenna, but his use of it for transmission WAS an innovation. So, how did it work? The truth is that Marconi not only had no idea how it functioned, he was none too concerned about his ignorance either, for it gave him what he wanted: distance. And this could be said of all of his antennas up to the outbreak of World War One.

Indeed, where Marconi was concerned, 'the original acts of creative insight were seldom his. Where he excelled was in the indispensable process of critical revision'. Time would prove the above judgement prescient.

When the 'syntonic' systems patented by Lodge in Britain and Braun in Germany failed to radiate sufficient energy, Marconi solved the impasse with '. . . two simple yet ingenious innovations'. He used an inductor to couple the antenna to the transmitter, in fact, two inductors placed closely together instead of the single coil used in many of the transmitters of the day. Furthermore, he made the inductances variable, along with the transmitter circuit capacitor. In short, he tuned his antenna and transmitter output circuit into resonance with each other. Consequently, a great deal of energy was now radiated into space and at one frequency only.

Five years after his discovery of the antenna, Marconi, despite scientific opinion, was achieving ranges of 60 to 100 miles. No more would ships be out of sight once over the horizon, nor proconsuls be able to ignore an imperial edict. The world of C^3 (Command and Control through Communications) was but a development or two away.

Hertz did not live to as much as glimpse the brave new world he had done so much to bring about. He died on New Year's day 1894, of blood poisoning, at the early age of 36.

In our own time, the SI unit of frequency measurement was renamed the Hertz in his honour.

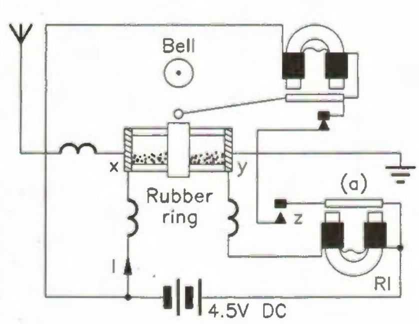

Figure 4. Alexander Popov's receiver.

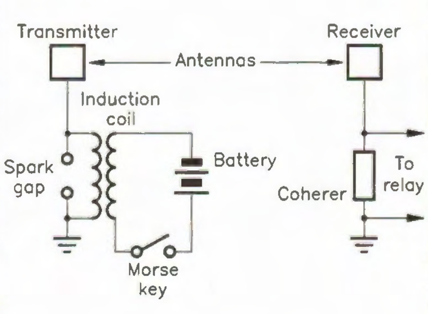

Figure 5. Marconi's experimental equipment, 1895.

Popov survived his antenna experiments by a decade, living long enough to note Marconi's successful experiments between Dover and Wimereau and his bridging of the Atlantic by radio. He died of a brain haemorrhage on the last day of December, 1905. His health had been affected by the harassment of the authorities, who were opposed to the democracy movement which Popov espoused, particularly for his students. He was 46.

Marconi, laden with renown, died in Rome on July 20th 1937, after the latest of several heart attacks. Thousands of mourners attended the state funeral and the Italian Radio System observed a 5-minute silence.

In Britain and its dominions across the world, the Post Office and the British Broadcasting Corporation (BBC) observed a two-minute silence. On that day, the world was, however briefly, reminded of the contemplative quiet it had known before the birth of the antenna.

References

Electronic Inventions 1745 - 1976. G.W.A. Dummer. Pergamon Press, Oxford. 1977. Page 50.

Science For The Citizen. Lancelot Hoghin. George Allen & Unwin Ltd., London. 1938. Page 755.

Syntony & Spark. H.G.J. Aitken. Wiley-Interscience, London. 1976. Page 132.

Ibid (3). Page 192.

Electronics World + Wireless World. Article 'Marconi Beginnings', January 1992. Page 74.

Ibid (3). Page 187.

From Spark To Satellite. Stanley Leinwoll. Charles Scribner's Sons, New York. 1979. Page 10.

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