HEINRICH HERTZ -- THEORIST AND EXPERIMENTER

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ABSTRACT

Heinrich Hertz made the first antennas and transmitter-receiver radio system and conducted a series of experiments which established in a brilliant way that radio waves are one with light except for their much greater length. His description of the radiation phenomenon remains the best ever written, revealing his tremendous depth of understanding of the subject. Hertz's training, studies and experiments are recounted and measurements with a replica of his apparatus are described.

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When 21 year old Heinrich Hertz entered the University of Berlin in the fall of 1878 he fell under the spell of a great seat of learning and in particular the influence of two famous pioneers of science, Gustav Kirchhoff and Hermann von Helmholtz.

Although his parents wanted him to become a construction engineer, his real love was for mathematics and physics. So after performing his military duties he pursued a scientific curriculum at the University of Munich and the Technical Institute there prior to entering the University of Berlin in 1878 where he studied under von Helmholtz. A prize had been offered for an experimental demonstration of the effect of electromagnetic forces on dielectric polarization and von Helmholtz urged Hertz to enter the competition. Hertz considered whether the demonstration could be done with oscillations using Leyden jars or open induction coils. He concluded correctly that the effect would be too difficult to observe and did not pursue the problem. However, the seeds of interest in oscillations had been sown.

As we have seen, Hertz had a broad diverse background and wide experience on which to draw. He was both a theorist and an experimenter. He possessed in every respect a "prepared mind".

A common piece of laboratory apparatus at that time consisted of 2 coaxially-mounted flat induction coils known as Knochenhauer spirals. A Leyden jar capacitor discharged through one coil induces a spark between the terminals of the upper coil.

In a series of steps Hertz replaced one Knochenhauer spiral by a straight wire having a spark gap at the center with a spark-producing induction coil connected across the gap. This straight wire Hertzian $\lambda/2$ dipole was a vital step because it was an open resonant system. Previous resonant systems were closed. In place of the other spiral, Hertz constructed a round or square single-turn loop with a small gap. This apparatus of dipole antenna and loop receiver was the first complete radio system.

Next Hertz succeeded in setting up standing waves on a long straight wire and measured the spacing between successive standing wave minima. This gave him the wavelength (equal to twice the spacing).

In another demonstration Hertz surrounded a long wire by a parallel-wire metal cage and found that when the cage was closed at its ends around the wire, current no longer flowed along the wire but rather outside the cage. He, thus, demonstrated the "skin-effect" or the restricted depth of penetration of rf into a conductor.

He further states "the disturbance in the wire itself is not, as has hitherto been assumed, the cause of the phenomena in its neighbourhood; but that, on the contrary, the disturbances in the neighbourhood of the wire are the cause of the phenomena inside it."

Next came observations of standing waves in air and then experiments on beaming, reflection and refraction. To concentrate or beam his 6 m waves Hertz realized that he would require a parabolic reflector of enormous proportions. Accordingly, he built a new system for 1/10 the wavelength (or 60 cm) with a spark-gap-fed $\lambda/2$ dipole 30 cm long at the focus of a cylindrical parabolic reflector of zinc sheet 2 m (or 3.3 λ) tall by 1.2 m (or 2 λ) across. This was for transmitting. For receiving he placed a center-fed full wavelength dipole at the focus of an identical parabola bringing a 2-wire transmission line from the center of the dipole through insulating bushings to the back side of the parabola where he installed an adjustable spark gap.

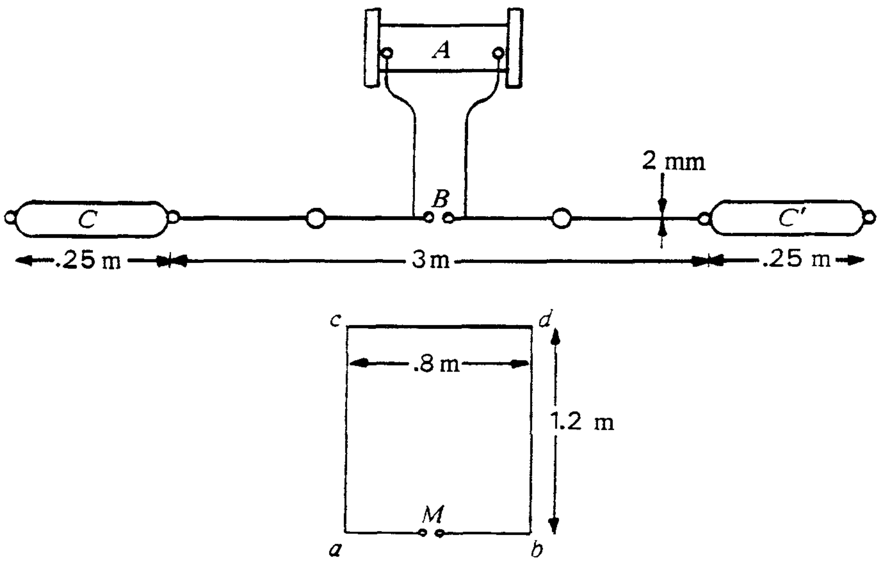
With these parabolas Hertz was able to observe the beaming of radio waves and could work to a distance of 16 m, transmitting his waves through a closed wooden door from one room to another in his laboratory. He then put his parabolas side-by-side and bounced his waves from one to the other via a large flat zinc sheet. He was able to demonstrate that the angle of reflection from the flat sheet equalled the angle of incidence.

To demonstrate refraction Hertz built a massive prism of asphalt 1.5 m high with 1.2 m sides meeting at a 30^{o} angle and placed it on a turntable between his parabolas. Measuring the angle of incidence and its deviation by the prism, Hertz was able to determine an index of refraction which was close to the optical value.

With parabolas vertical and facing each other, response was a maximum but turning one parabola horizontal reduced the response to zero demonstrating linear polarization. With both parabolas again vertical, he placed a large grid of vertical parallel wires between the parabolas cutting off transmission. But if the grid wires were set at an angle or turned horizontal a response was obtained. Further, with transmitting parabola vertical and receiving parabola horizontal for zero effect, inserting the grid at an angle produced a response.

Hertz's demonstrations of the similarity of his waves to light are impressive and especially so when you view the size and extent of his apparatus.

Hertz's epoch experiments constitute a milestone in science. From his simple, yet effective, apparatus has come all of radio communication, AM, FM, and TV and radio links that span the solar system. To Heinrich Hertz, humankind owes a great debt of gratitude.



Heinrich Hertz's transmitting dipole and receiving loop. The first radio system.