Hertz

Heinrich Hertz — you may think you know him as the father of stereo component specifications. However, his work was much more important; he discovered radio waves!

AFTER SO MANY years of calling the units of frequency cycles-per-second, it still takes old-timers a while to get accustomed to using the name Hertz. Surprisingly few people associate the name Heinrich Rudolf Hertz with the discovery of radio waves, but the use of Hertz (usually shortened to Hz) to denote frequency shows a deserving recognition of this fact.

Hertz was born in 1857 and after a distinguished school life, he entered Berlin University to study under the celebrated Helmholtz. Helmholtz was one of the last of the great Victorian scientists, one of those men who are equally happy in any branch of science. Two of his contributions to physics are still remembered in the textbooks: the Helmholtz coils and the Helmholtz resonator. A pair of Helmholtz coils consists of identical coils spaced one coil-radius apart, and their peculiarity is that the magnetic field between them varies only slightly from place to place between the coils. The Helmholtz pair is therefore the starting point for any TV deflection coil design. The Helmholtz resonator is a bottle with a narrow neck and its resonance to sound waves is decided by the volume of the bottle and the dimensions of the neck. If you happen to be in the business of designing cabinets for hi-fi loudspeakers, then the Helmholtz resonator is pretty important. All in all, young Hertz must have had a good grounding both in electromagnetism and in wave motion, and the success of his studies was recognised in the award of a doctorate by the University in 1880.

He started on a career of research in electromagnetism. In 1883 he became aware of Clark Maxwell's work on electromagnetic theory, a brilliant but neglected work which predicted the existence of waves which would be invisible, but which could travel at the speed of light. Hertz was convinced that Maxwell's theory was correct, and that these waves existed in reality as well as in mathematical equations.

Hertz directed his very considerable experimental ability to the problem of generating and detecting electromagnetic waves. He reasoned that very high frequency oscillations should behave in a way similar to light waves, and decided that the resonant circuit around a spark-gap would probably provide the best conditions of generating suitable oscillations.

His apparatus, shown in Fig. 1, is now one of the famous landmarks in radio history. It consisted of an induction coil capable of generating about 30 kV of low-frequency AC, and a spark gap between two copper spheres. The inductance of the leads to the spheres plus the capacitance between the spheres constituted a resonant circuit. The resonant frequency was high, much higher than the frequencies which were to be used later by Marconi and others. Recreation of Hertz's experiment has, in fact, shown that the strongest transmitted frequencies were in the lower microwave range.

The receiver was equally simple, as can be seen from Fig. 1; a pair of copper spheres at the ends of short pieces of wire. This constitutes what we would now call a dipole aerial, and the principle on which Hertz was pinning his hopes was that electromagnetic waves picked up on the wires would create a sufficiently large electrostatic field to ensure a high voltage across the gap between the spheres. Hertz's ideas worked out perfectly. When the transmitter was sparking away, sparks could also be seen between the spheres of the "receiver". There was no connection of any sort between the transmitter and the receiver. None, that is, apart from the electromagnetic waves which Maxwell had so confidently predicted in 1864. It was a perfect vindication of Maxwell's theory, but the evidence was not strong enough for Hertz.

Hertz felt that, in order to vindicate Maxwell's theory fully, he must show that there were waves passing from the transmitter to the receiver, and that these waves were physically similar to light waves. He started on a long and ambitious project of discovery using methods which were ideally suited to the short wavelengths which his equipment generated. Oddly enough, had he generated lower frequencies, his measurements would have failed: these are the sort of happy accidents which continually seem to occur in the history of science.

Practical Measurements

Measurement of the wavelength of the radio waves was the first objective. The standard method of measuring the wavelength of light makes use of wave interference. Light from a

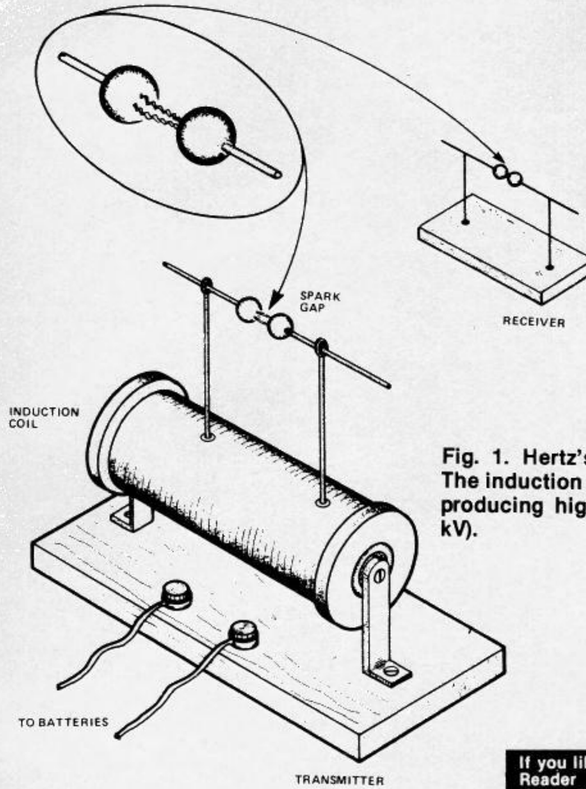

Fig. 1. Hertz's transmitter and receiver. The induction coil is a DC to AC converter producing high-voltage pulses (about 40 kV).

source is split into two beams (Fig. 2) and these beams are aimed at a screen. Light rays which have travelled exactly the same distance will reinforce, causing a bright spot, but when the distance difference between the paths is half a wavelength, or any odd multiple (3,5,7,9, etc) of half a wavelength, the waves cancel, causing a shadow. By measuring the distances between these "fringes" of light and dark, the wavelength of light can be calculated.

Hertz used this technique, but since the waves could not be seen he had to use small spark-gap detectors instead of a screen. The wavelength of his apparatus turned out to be a few centimetres.

Hertz also measured the speed of the waves, using, once again, a version of the classic methods for measuring the speed of light. These make use of mirrors revolving so fast that a ray of light which has been delayed by travelling a long distance to a reflector and back finds the mirror at a different angle when it returns, so shifting the reflection. The amount of the shift, together with the speed of rotation of the mirror and the path distance, can be used to calculate the speed of the light.

To make this measurement, Hertz had first to establish that radio waves were reflected, and he was delighted to find that the newly discovered waves reflected from metal sheets in exactly the same way as light waves do, with the angle of reflection equal to the angle of incidence (Fig. 3). He also found, incidently, that radio waves were refracted; that is, they changed direction as they passed from one material to another exactly as do light waves.

Having made these points, Hertz succeeded in measuring the speed of the new waves. This speed turned out to be 300 million metres per second, the well established value for the speed of light. Hertz now felt that he had indeed discovered some of the waves which Maxwell had predicted. The work had taken him four years, from 1885 to 1889.

Road To Radio

In 1889, Hertz was appointed professor of physics at Bonn University. His work with electromagnetic waves was over for the time being, and his new line of research was to be on gas discharges, following the work of Geissler. His report, "Electric Waves", was not published until 1893, because his health was seriously declining; a lung infection which he had disregarded was now recurring.

He died in 1894, aged 37, with a brilliant career behind him, and a promise of much more to come. His "Miscellaneous Papers" was published in 1894, and his "Principles of Mechanics" in 1899. These works were not his epitaph, though they hinted at the remarkable discoveries which he might have made. There is little doubt that long-distance radio would have been established much earlier than 1910 had Hertz lived. As it was, his work started an immense frenzy of experimental activity, of which the work of Marconi is best known to us. We shall remember, though, that Hertz's work caused immense excitement, and practically every country can boast of a radio pioneer. Of these who disputed Marconi's claim to be first with long-distance radio transmission, Tesla in Czechoslovakia and Popov in Russia were both serious contenders.

There is no dispute about the source of the work, though. Maxwell blazed the trail, and Hertz built the road along which all the later radio experimenters travelled. Now that we no longer measure magnetic flux in maxwells, it seems entirely appropriate to measure frequency in hertz. ETI

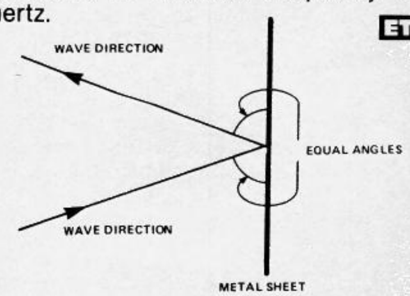

Fig. 3. Wave reflection. Radio waves are reflected from a metal sheet in just the same way as light waves are reflected from any mirror.

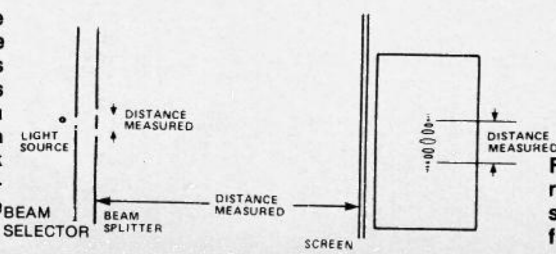

Fig. 2. The method Hertz used to measure wavelength of light: (a) a slit in an opaque sheet selects one ray of light, which is then split into two by close-spaced splits in another sheet. The image projected on the screen (b), when examined with a microscope, consists of alternate dark and light bands caused by wave interference. The wavelength can be calculated from the distances indicated.