

## The 1896 Magnetic Detector of Lord Ernest Rutherford

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Fig. 1. Ernest Rutherford from a pastel by R.G. Mathews in 1907.  
The Rutherford Museum of McGill University.

**A** number of prominent biographies of Marconi describe his work in 1900 on a magnetic detector to replace the unreliable coherer<sup>(1-3)</sup>. The magnetic detector was based on an earlier invention of Ernest Rutherford<sup>(4)</sup>. Since the details of the discovery had been largely overlooked by wireless historians, I set out to trace the work of Rutherford at a place not far from my former home at McGill University in Montreal, Canada.

### Ernest Rutherford

Born in 1871 near Nelson, New Zealand, Rutherford was the fourth of 12 children. In 1891 he graduated from secondary school with a scholarship to Canterbury College in Christchurch. He

earned a BA in mathematics and physical science in 1892, and a MA in 1893. He then conducted 2 years of research on magnetism and the detection of Hertzian waves. In 1894 he won a scholarship to the Cavendish Laboratory at Cambridge University in England where he studied under JJ Thomson. He continued his research on magnetism for another 2 years<sup>(5, 6)</sup>.

In 1896 Rutherford turned to the study of X-rays after their discovery by Conrad Roentgen in 1895. He used ionization as a tool for studying radioactivity, and thereby discovered the heterogeneous nature of alpha versus beta rays. In 1898 he was appointed Macdonald Professor of Experimental Physics at McGill University in Montreal, Canada. He was 26. In nine years at McGill, he researched many aspects of radioactivity. During these years he published 69 papers. Note that this was well before the advent of word processing!

In 1907 Rutherford returned to England to become Langworthy Professor of Physics at the University of Manchester. In 1908 he was awarded a Nobel Prize in chemistry for his work on radiation. He was knighted in 1914, becoming Sir Ernest Rutherford. In 1931 he was created First Baron Rutherford of Nelson, NZ, and

Cambridge.

### **The Rutherford Museum**

Apparatus for a physics experiment would be constructed in the department's machine shop. After the experiment, apparatus would be returned to the machine shop to be "cannibalized" for materials. At McGill, because of his growing renown, Rutherford's radiation apparatus was saved. The collection of radiation apparatus became the core of The Rutherford Museum at the University. I began my undergraduate career in the Physics Department at McGill. One of my professors was Dr. Ferdinand Terroux, a former graduate student of Rutherford, who became the first curator of the Rutherford Museum.

No such fate appears to have preserved Rutherford's earlier magnetism apparatus. There is, however, a clear photograph remaining in a published paper of his magnetic detector<sup>(7)</sup>.

### **Studies in Magnetism**

Rutherford published three papers on various aspects of magnetism<sup>(4, 8, 9)</sup>. The third paper investigated the following subjects: Magnetization of iron

by high frequency discharges and the effect on short steel needles; detection of electro-magnetic radiation in free space; waves along wires; damping of oscillations; and determination of the period of Leyden jar discharges and the constants of the discharge circuit.

Rutherford reported the following findings: Magnetization is largely a surface phenomenon (discovered by dissolving magnetized materials in acid). The magnetization of a surface layer was always in the opposite direction to the internal magnetization. Whenever a magnetized needle was placed in a solenoid and a Leyden jar discharge passed, there was always a reduction of magnetization. An un-magnetized needle, on the other hand, was not appreciably magnetized by being placed in a Leyden jar discharge circuit.

### **Detection of Waves in Free Space**

Rutherford reports: "The amount of demagnetization of a magnetized needle depends on the fineness of the wire and the number of turns on the solenoid. If a short piece of thin magnetized steel wire be taken, and a large number of turns wound over it, it is a very sensitive means of detecting electrical oscillations in a conductor when the amplitude of the oscillations is extremely small".

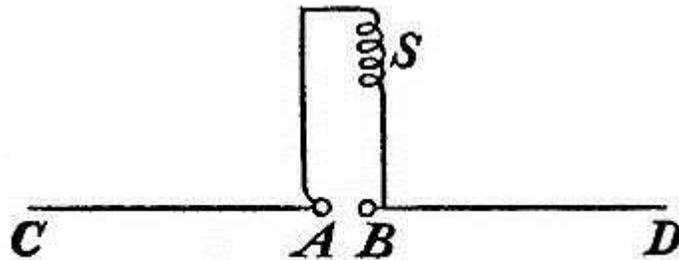


Fig. 2. Schematic representation of Rutherford's detector from his 1897 paper.

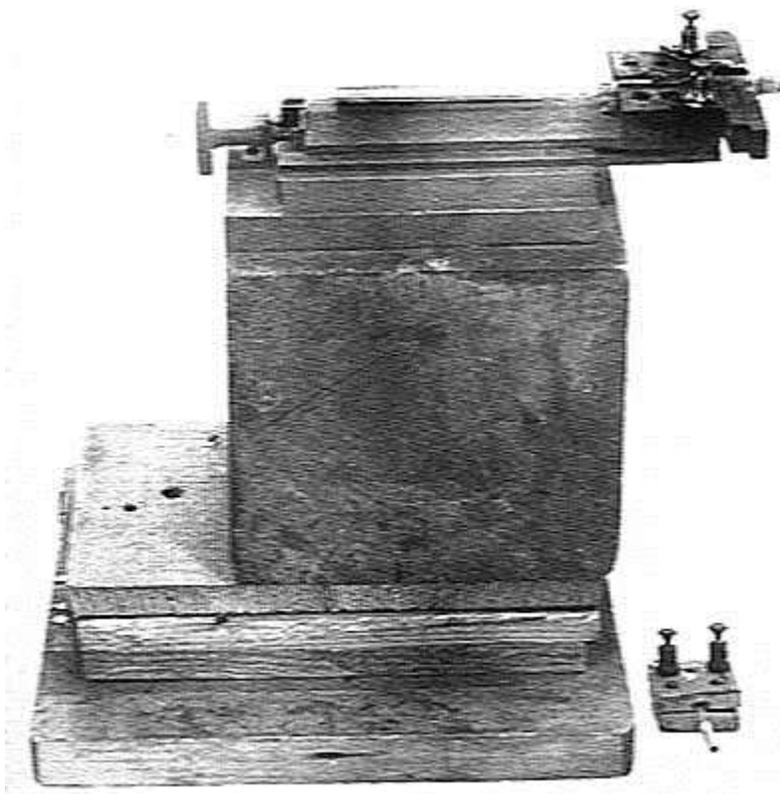


Fig. 3. Rutherford's original detector as shown in his 1897 paper.

### Design of the Detector

About 20 pieces of steel wire were taken, 0.007 cm. in diameter (about 24 AWG). Each was 1 cm. long and insulated with shellac. Then a wire solenoid was wound directly over them consisting of two layers of 80 turns/cm. This assembly was then fixed at the end of a glass tube and the tube in turn was fixed on a wooden base.

A schematic representation is shown in Figure 2. *S* represents the detector needle and solenoid wound over it. *A* and *B* are mercury cups. *CA* and *BD* are two straight rods as receivers. Rutherford

never specified the length of the rods. Rutherford's original detector is shown in Figure 3.

### Constructing a Replica

I decided to try to replicate Rutherford's detector. The task did not appear to be too challenging and the materials seemed readily available. I began with pieces of core wire from a damaged "HedgeHog" audio transformer. They were 24 gauge and I cut about 20 pieces 1 cm. long. These were then coated with shellac. When dry, I tied them in a bundle and shellacked the whole bundle. I then wrapped them in 1 cm<sup>2</sup> of paper and shellacked them again.

I measured the diameter of the bundle at 3.5 mm. I punched 3.5 mm. holes in bits of card and installed these on each end of the bundle as spool ends, then applied more shellac. The

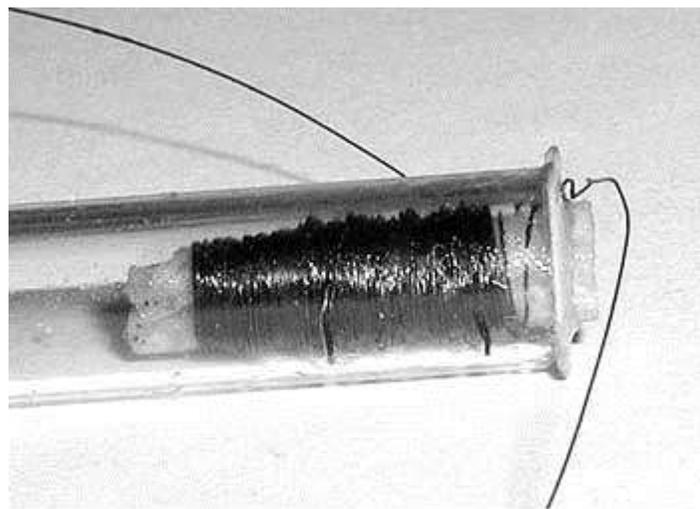


Fig. 4. My replica of the solenoid as described in the 1897 paper.

spool was mounted on a sewing needle and glued with shellac. Rutherford had specified 160 turns of wire. According to wire tables, that needs #37 wire. I had #36. The assembly was mounted on a Morris coil winder, and 160 turns were applied in about 3 layers. The resulting solenoid was fixed with shellac in one end of a 5 mm. ID glass tube, 13 cm. long, fashioned from a pipette. The glass tube appeared to function mostly to protect the solenoid during handling. Two leads were brought out from the end of the tube (Figure 4).

Actually I made two solenoids. The "HedgeHog" transformer wires did not work well, and were replaced with 10 - 1 cm. lengths of 19 ga. stovepipe wire. The resulting solenoid was mounted on wood as seen in Figure 5. The "antenna" was 2 brass plates 6"x6", mounted on 1/8" diameter brass rods, around 9" long. The D.C. resistance of the solenoid was 4.5 ohms.

### Test Procedure

Rutherford said to first magnetize the "needle" with a permanent magnet or D.C. current through the solenoid. Then measure the deflection with a magnetometer. Next, submit the solenoid to a Hertzian discharge. Finally, measure the deflection again. Each of the steps required the operator to move the solenoid from one piece of apparatus to another. We can readily see that this was not the efficient operating detector that Marconi needed.

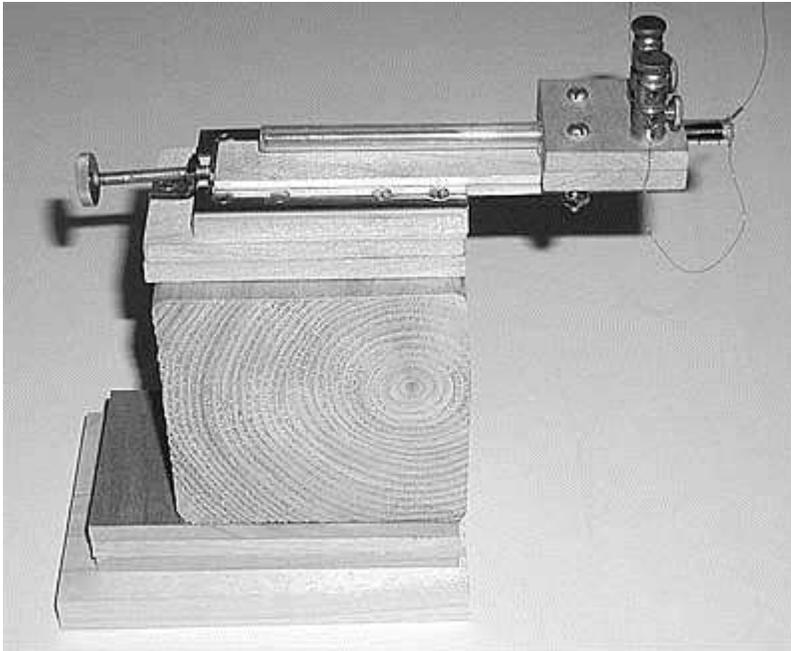


Fig. 5. My replica of Rutherford's magnetic detector.

### Ruhmkorff Coil

Rutherford tried both a Hertzian vibrator and a Ruhmkorff coil of unspecified size. I used a small spark coil in a 2" by 5" oak box, powered by 6 volts D.C., and an early radio spark gap set at 1/4". I mounted two 6"x6" brass plates on 1/8" diameter 9" brass rods and fixed them to the coil as an antenna. Rutherford used 40 cm<sup>2</sup> (16"x16") plates. My arrangement only worked over a 10" distance sufficiently to fire a NE-51 lamp.

I made a magnetometer by mounting a compass in cardboard such that the glass tube containing the solenoid and "needle" was always in a constant position with respect to it. I have never seen a laboratory magnetometer. I then made a new model with the compass mounted in oak. Otherwise it worked much the same way.

### Results

Magnetizing the core with 1.5 volts D.C. through the solenoid (150 mA.) did not transfer enough energy to magnetize the core reliably. The reading on the compass

(magnetometer) tended to be almost the same after magnetization and after discharge (around 18 degrees from North). I conducted 30 trials while manipulating various parameters.

I got stronger results after magnetizing the core with a permanent magnet. The core then pulled the compass 28 degrees away from North. Then exposure to a spark discharge gave a measurable decrease in magnetization. The core then pulled the compass 18 degrees from North. I was able to replicate this result several times. After this I tried to magnetize the core with 6 volts D.C. (around 1 amp) through my coil of #36 wire. The core still measured only 18 degrees on the magnetometer. I did not expect the replication of this experiment to be as difficult as it was.

### **Questions I Could Not Answer**

Why did Rutherford use Mercury cups?

What configuration and dimension of antennae did he use (in 1896 tuning had not been invented)?

Why did he raise the detector on wood shims?

Why did he use a vernier horizontal adjustment?

What duration of spark did he apply?

What was the size of his Ruhmkorff coil?

Rutherford said he magnetized wire with 100 amp currents.

His editor said he was an indifferent proofreader. Who should we believe?

### **Marconi's Magnetic Detector**

Rutherford's detector was purely a laboratory demonstration. Marconi developed his "maggie" in 1902, applying the same magnetic principles. He made the apparatus practical for receiving code by continuously magnetizing and demagnetizing a moving steel rope. Although code speeds of the day were not high by more recent standards, Marconi's detector could handle a stream of code without being manually reset. Replicating Rutherford's experiment gave me a new respect for both Rutherford's and Marconi's persistence and skill.

### **Acknowledgements**

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