The Early Electronic Uses of Nothing

A Presentation on Early Vacuum Devices in Communications, Industry, and Computation, for the

American Vacuum Society

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Presentation Venue

Electronic Use of Nothing

- The history of the discovery of the uses of nothing, i.e., vacuum, pleases the mind. Galileo may have been the first modern to investigate vacuum.

- A deep principle is at work: eliminate the equivalent of "friction" and see (and enjoy and exploit) the true operation of nature. Newton's celestial mechanics also illustrate this principle, which has an analogy in economics as well in Nobel Prize winner Ronald Coase's notion of "transaction costs."

- In communications, Guglielmo Marconi utilized a vacuum device about 1896. The "coherer" detected radio frequency energy rendering it sensible to people through other devices. Marconi evacuated this device in hopes improving its performance.

- Vacuum electronic technology ranged from analog wireless telegraphy to digital computation.

Guglielmo (“Bill”) Marconi

Marconi and his assistant George Kemp pose with a telegraph inker as if reading a wireless message, *c*. 1907

Electronic Use of Nothing

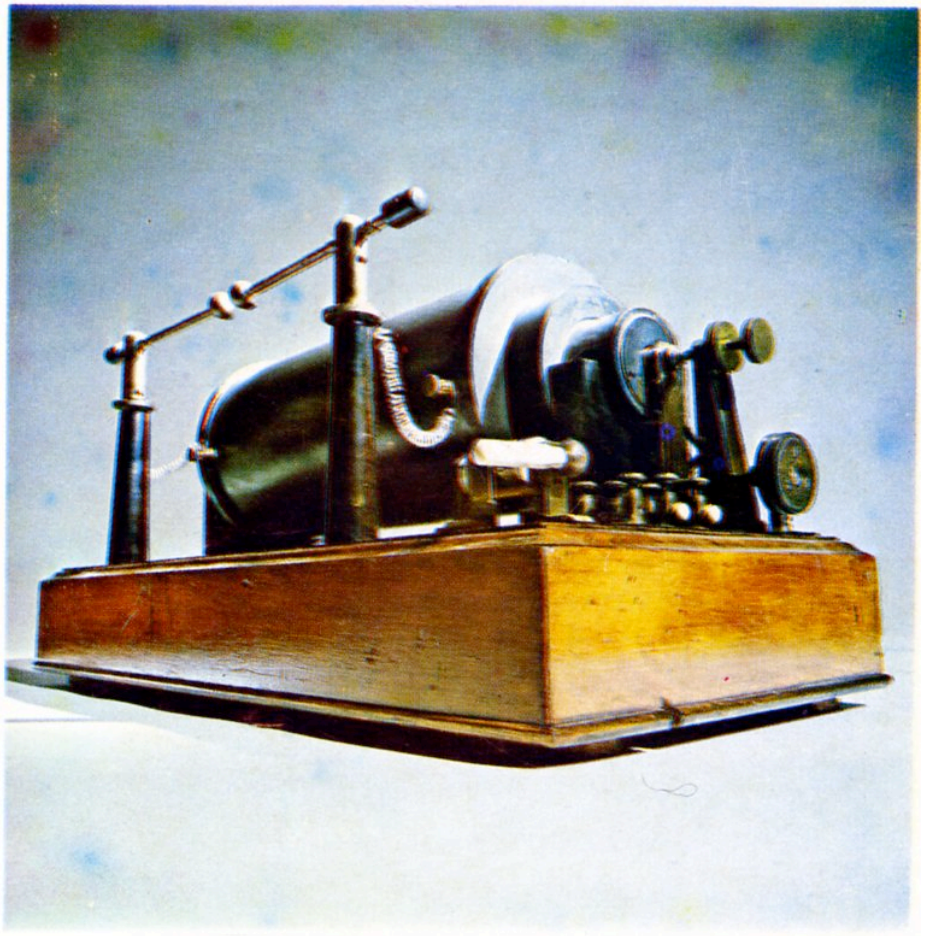
- Communications pioneers also used vacuum devices to detect the signals of the then new wireless telegraphy. Tesla first suggested a vacuum device detector in the early 1890s.
- Notably, Marconi, through the work of John Ambrose Fleming, implemented the vacuum diode in 1904, the "Fleming Valve," thereby advancing the art and commerce of radio.
- Lee deForest put the famous "grid" between the filament cathode and anode of the Fleming vacuum diode, in 1907, and created the primary technology of 20th century communications and electronics, the triode vacuum tube as an amplifier and oscillator.
- When Fleming heard about that innovation, he is reported to have said: "I wish I'd thought of that!"

The Coherer, the First “Detector”

- The Edouard Branly coherer, about 1890, provided the first practical way to detect Hertzian waves as generated by a Ruhmkorff coil (induction coil) spark generator; Marconi improved it.
- These spark pulses could be fed to an antenna and ground. With its own antenna and ground, a DC biased coherer could detect each pulse.
- When so pulsed in the patterns of Morse code, messages could be transmitted without wires, Marconi’s vision.

A RUHMKORFF SPARK COIL, JUST ADD AN ANTENNA AND GROUND, AND KEY THE PRIMARY INTERRUPTER:

ABOUT TWO FEET WIDE, CAPABLE OF A FIVE INCH SPARK BETWEEN ELECTRODES



Source: Sparks, III, SWOP, 1974

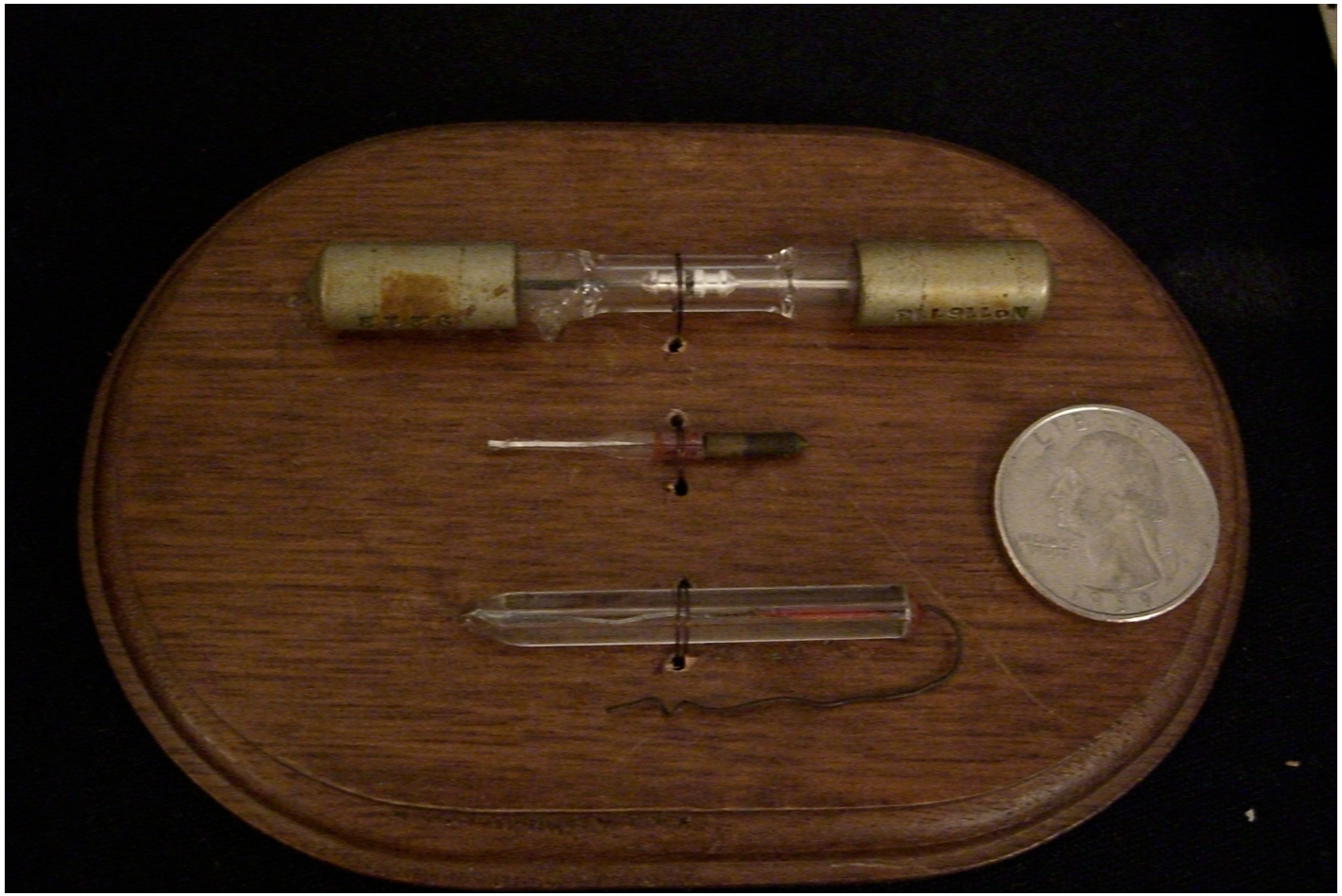
Coherer Schematic

The filings show high resistance to a direct-current DC voltage across the plugs. When a radio frequency (RF) alternating current (from a spark transmitter) goes from an antenna, through a plug, through the filings, through the second plug, and to ground, then the filings appear to "cohere," and then conduct the DC voltage in its circuit until mechanically interrupted.

That DC was fed back to a bell clapper to mechanically tap the filings back to non-conductance (decoherence) for receipt of the next RF pulse. The DC circuit could control a telegraph inker, a relay or be heard on headphones.

Adjustment of the tapper to a very fast rate provided DC current modulated by the length of the RF pulses received, e.g., dots and dashes.

Filings coherer, *c*. 1905 -



In Service with de Forest in Puerto Rico as early as 1905. From an AWA Presentation, 2009, photo Bart Lee.

Marconi Vacuum Coherer

Marconi about 1896 evacuated the coherer (the 5 inch glass tube below an ivory rod) to 1/1000 of an atmosphere (according to his patent application), likely to avoid oxidation and arcing corrosion in the filings. Such filings tend to adhere in a vacuum, which may promote the coherer effect – to this day not well understood.

Image from Howard Stone, Ph.D., by permission www.stonevintageradio.com

Coherer strapped to Rod, Evacuation Tube Above

Replica, image from Wikipedia, “Coherer,” about four inches long; with beveled contacts, rotation of the coherer by the stem could change its characteristics and sensitivity.

Very Early Marconi Coherer Receiver for Wireless Telegraphy

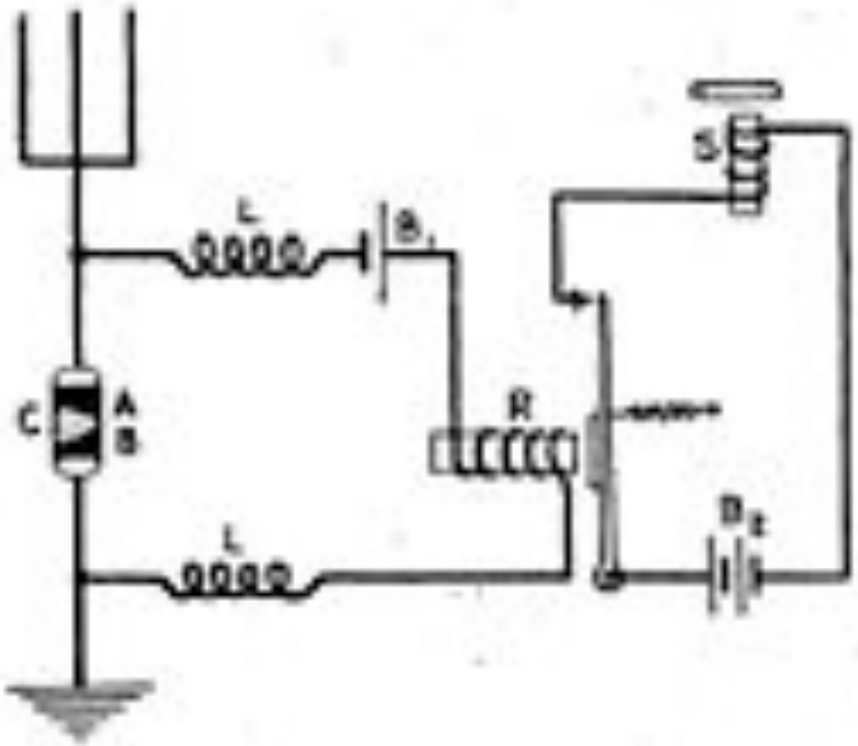
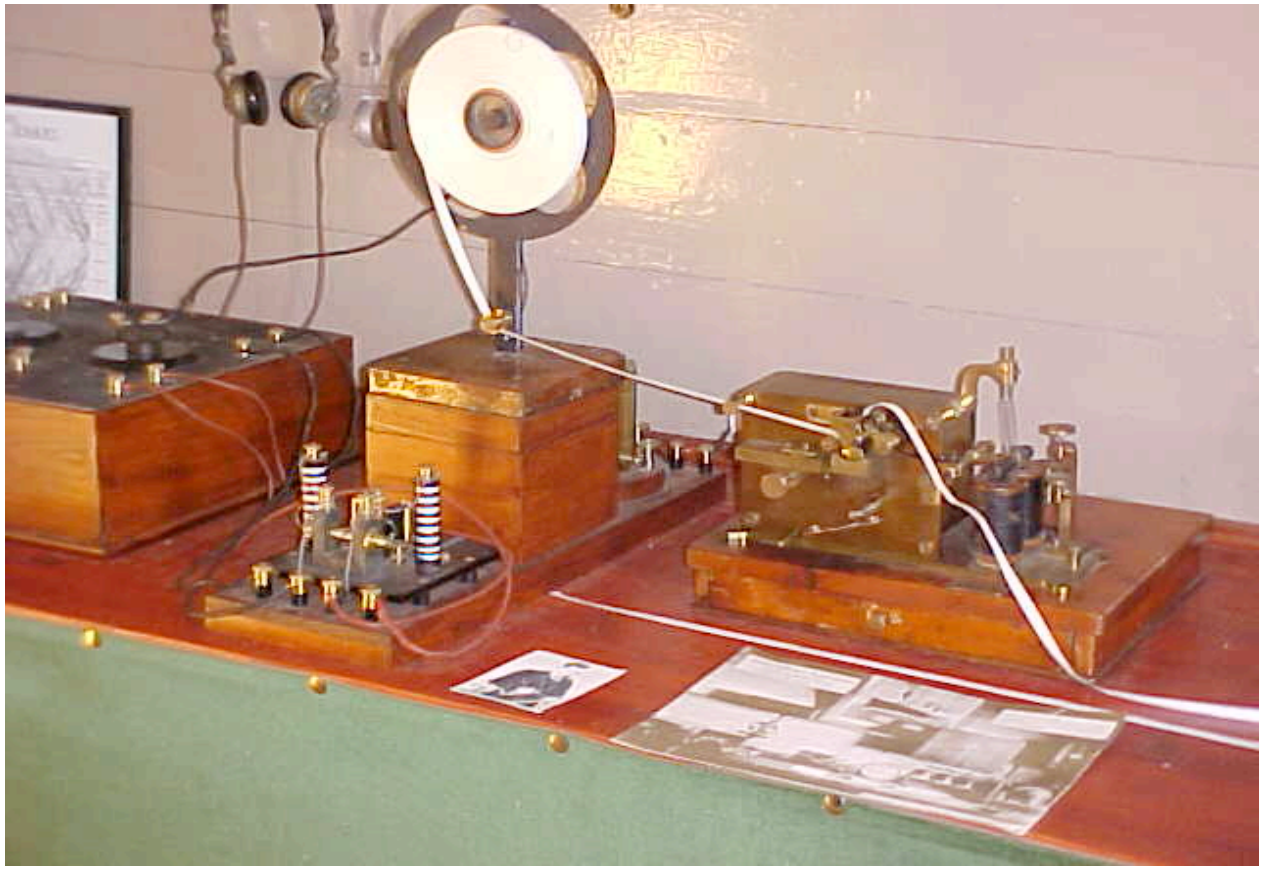


Fig. 101. Marconi 1896 Receiver.

Coherer =C; Battery for Bias = B1; Relay = R; Sounder = S; Battery for Sounder = B2. This is a non-linear gain circuit; little power at the antenna controls B1's then B2's greater power.

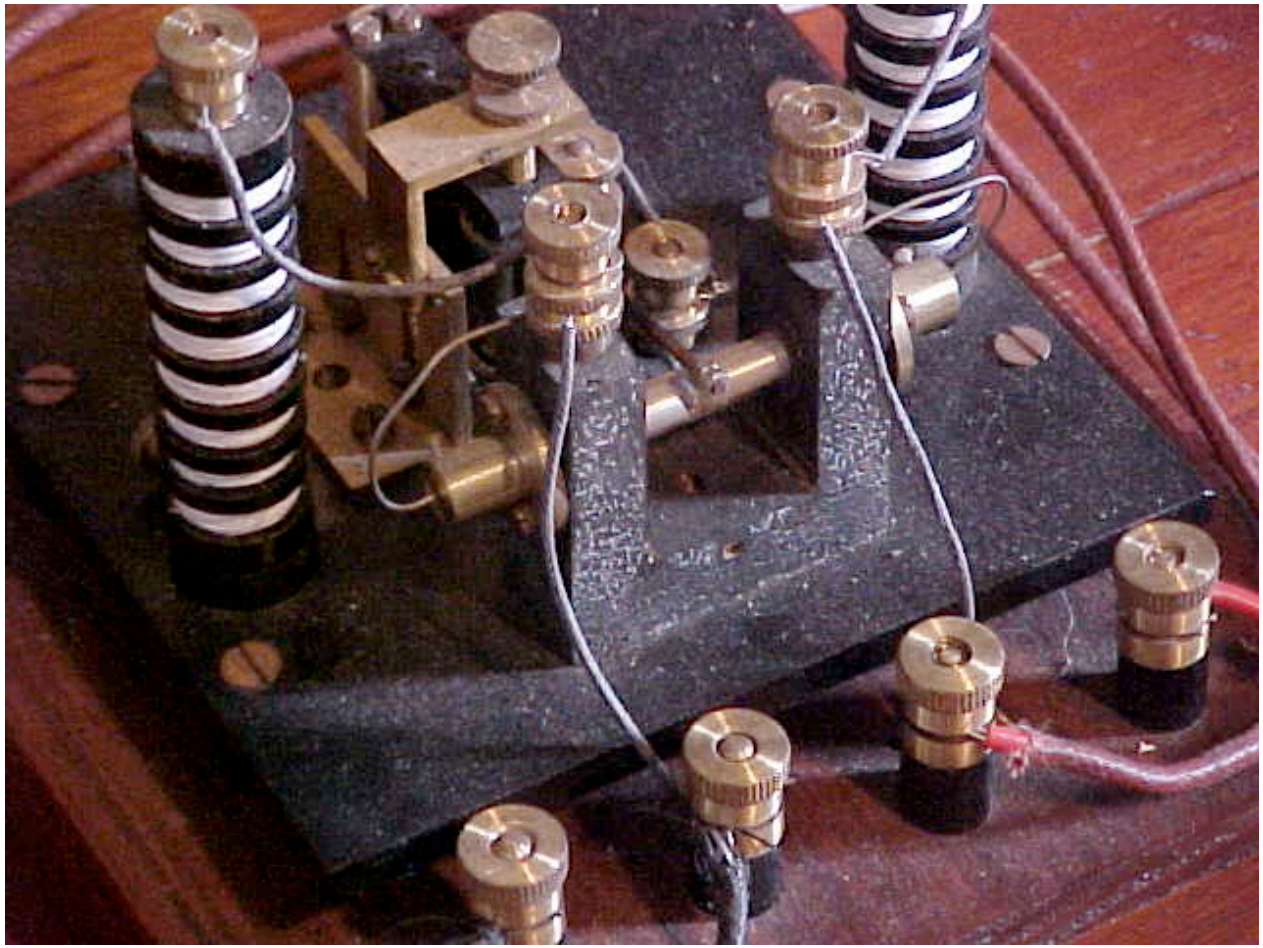
The Marconi “Lizard” Wireless Station with Coherer Detector, *c.* 1905



Marconi Lizard, Cornwall, UK Wireless Station, David Barlow Curator; photo Bart Lee 2005; Coherer appears front left, with striped insulators, the inker is to the right of it.

Marconi Rapid-Tapper Coherer at Lizard Wireless,

The rapid tapping as RF is received from a dot or dash, and the electromechanical characteristics of the circuit and inker, serve to integrate the taps of interrupted DC into rough longer pulses to operate the inker as dots and dashes. Such Morse code was all there was in the ether to detect at the time.

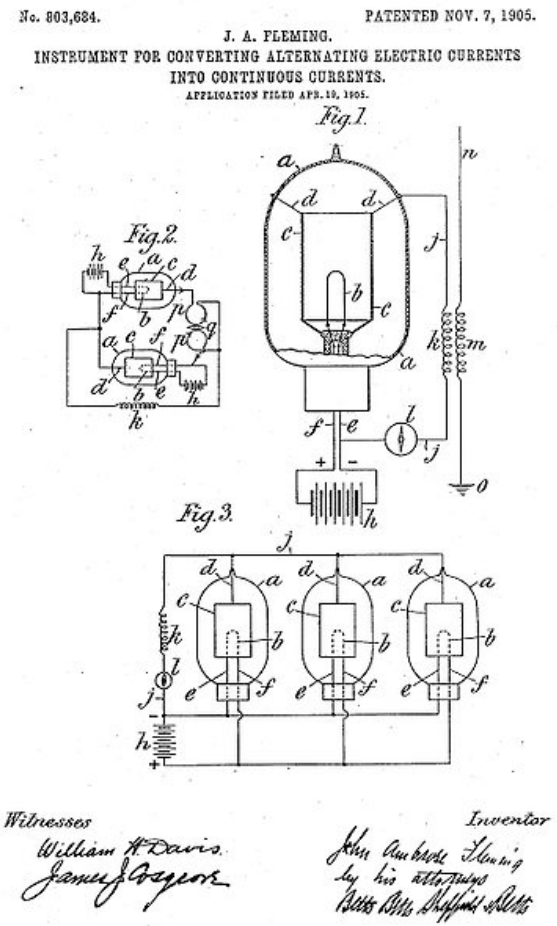


About six inches wide and six inches high; photo Bart Lee 2005.

John Ambrose Fleming

Inventor in 1904 of the first vacuum thermionic device in used in communications, the two element “valve” with a cathode and an anode, based on the Edison Effect in a light bulb with a plate.

Fleming's US Patent figures, note antenna and ground at right



No. 803,684. PATENTED NOV. 7, 1905.

J. A. FLEMING.

INSTRUMENT FOR CONVERTING ALTERNATING ELECTRIC CURRENTS INTO CONTINUOUS CURRENTS.

APPLICATION FILED APR. 19, 1905.

Fig. 1.

Fig. 2.

Fig. 3.

Witnesses
William H. Davis.
James J. Joyce

Inventor
John Ambrose Fleming
by his attorneys
Bates Bliss Hoffman & Bates

Very early Fleming Valve Diode

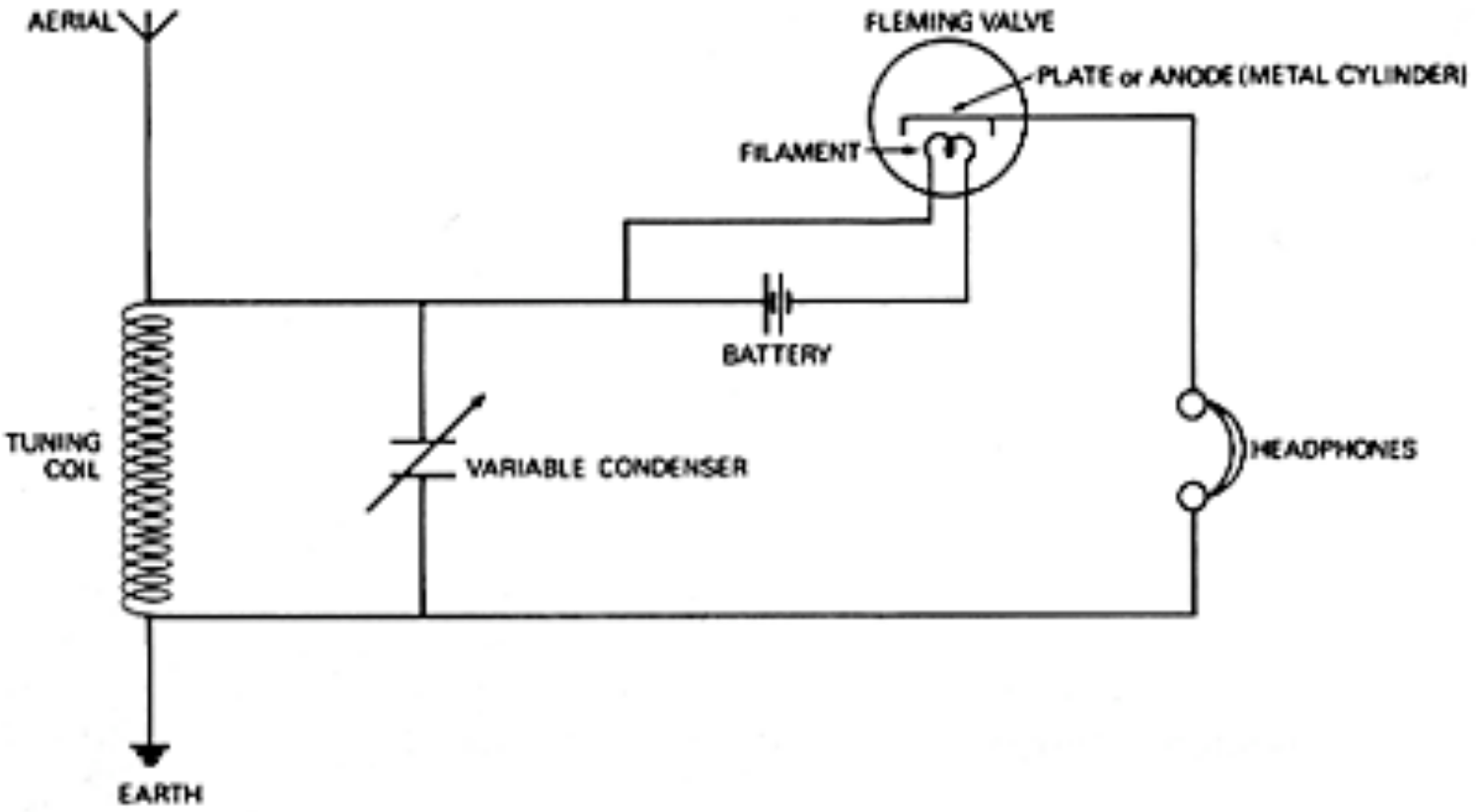
About four inches wide, in the British Museum, photo Bart Lee, 2002.

Very early Fleming Valve Diode

In the British Museum, photo Bart Lee, 2002.

Fleming valve diode receiver,

a “crystal-set” before the discovery of the semiconductor properties of various minerals, using instead a vacuum diode



1904 State of the Art

- The Fleming valve provided stability in wireless service. It defined the state of the art in 1904.
- Other detectors such as Fessenden's electrolytic detector worked but were unsuitable for service at sea. The stable Dunwoody/DeForest/Pickard carborundum crystal detector implementations were several years in the future. The Marconi magnetic detector was insensitive and electro-mechanical.
- None of these detectors (after the coherer) amplified the signals. Linear amplification would be the next plateau in the evolution of thermionic electronic devices.

Lee de Forest,

Inventor of the Vacuum Tube Triode

Image from Mike Adams,
The Complete Lee de Forest,
at www.leedeforest.org

A lot can and has been said of Lee de Forest, good and bad, but he really did Invent, in late 1906, the device that made modern electronics possible, including radio, television, RADAR, automation and computers. He called his triode the “Audion.”

Three Element Triode, *c.* 1907

The filament, at the right, is powered through the lamp base. The leads for the plate and the grid come out the top.

About two inches wide, in the British Museum, photo Bart Lee, 2002; probably made by Fleming for the Marconi company.

Three Element Triode

In the British Museum, photo Bart Lee, 2002.

DeForest
Three
Element
Triode
‘Audions’
Puerto Rico
c. 1909+

(An AWA Display, 2009, photo Bart Lee)

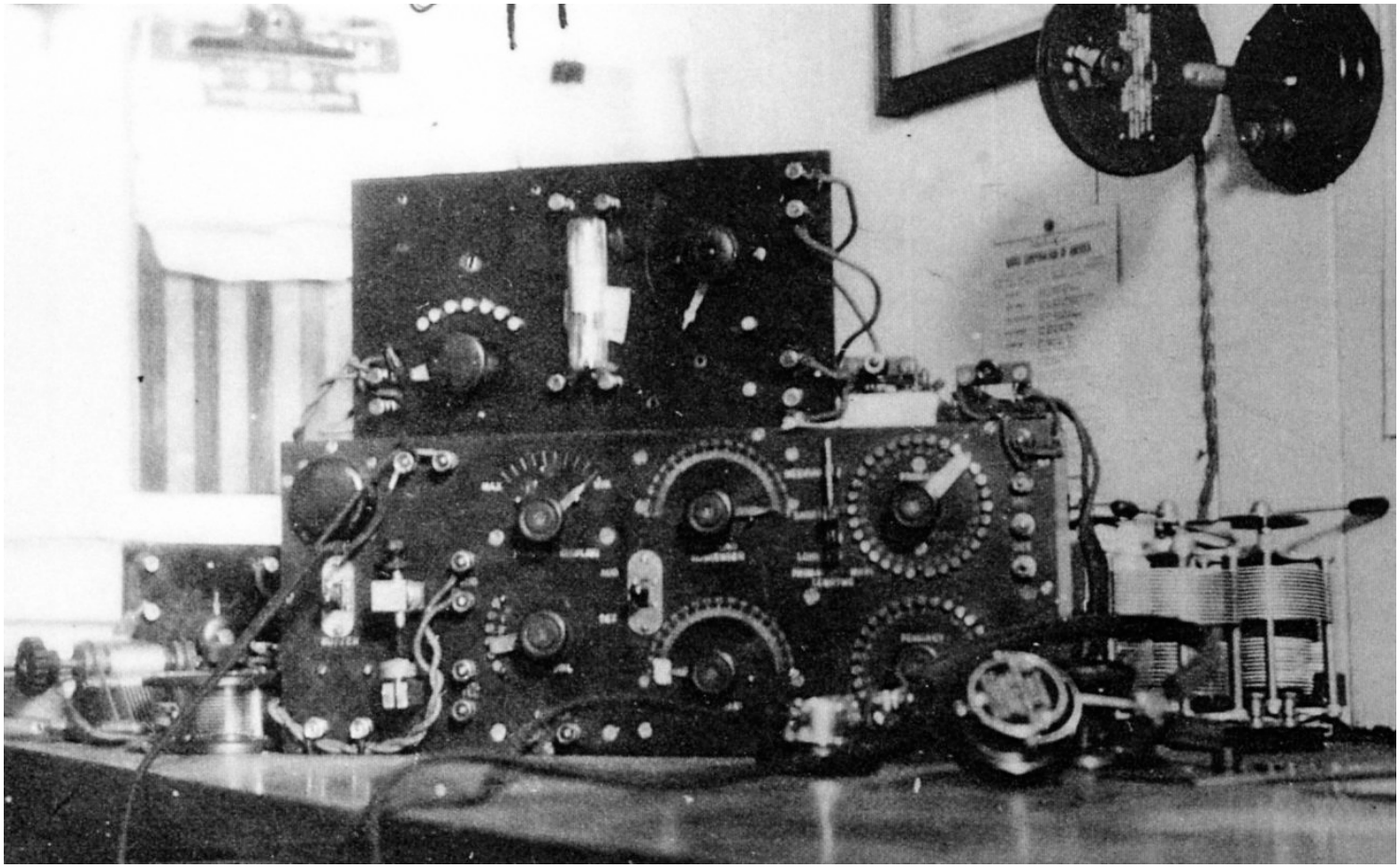
DeForest
Three
Element
Triode
‘Audion’
Puerto Rico
c. 1909+

Triode Detection, Amplification and Regeneration of Radio Signals

G.E. made the first hard-vacuum triodes; de Forest preferred a little gas in his.

A 1916 ad for an RJ 8 detector from Roger de Forest's site: www.deforestradio.com

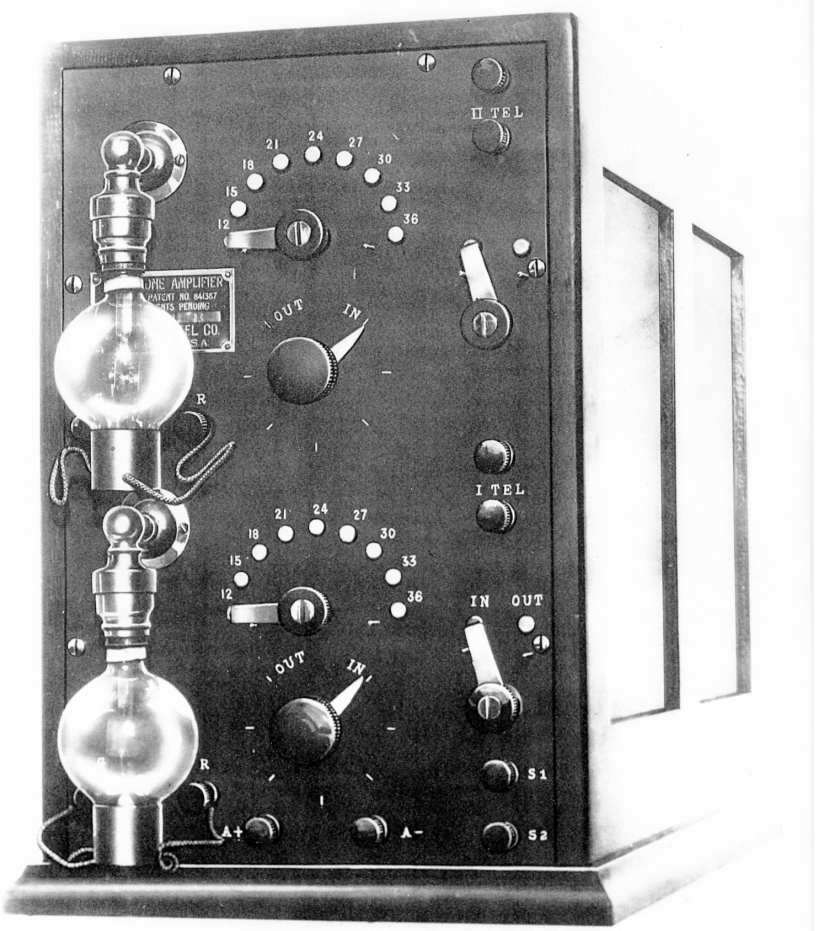
Triode Detector in Receiving Service



Circa 1916 photo, Perham Foundation Collections now at History San Jose

De Forest Triode Cascade Amplifier, Federal Telephone and Telegraph, Palo Alto, California 1912

AT&T bought the rights to use the triode in telephone service (long lines) in 1913



Photo, Perham Foundation Collections now at History San Jose

Edwin Howard Armstrong, inventor (maybe) of Regeneration

Graphic from Wikipedia

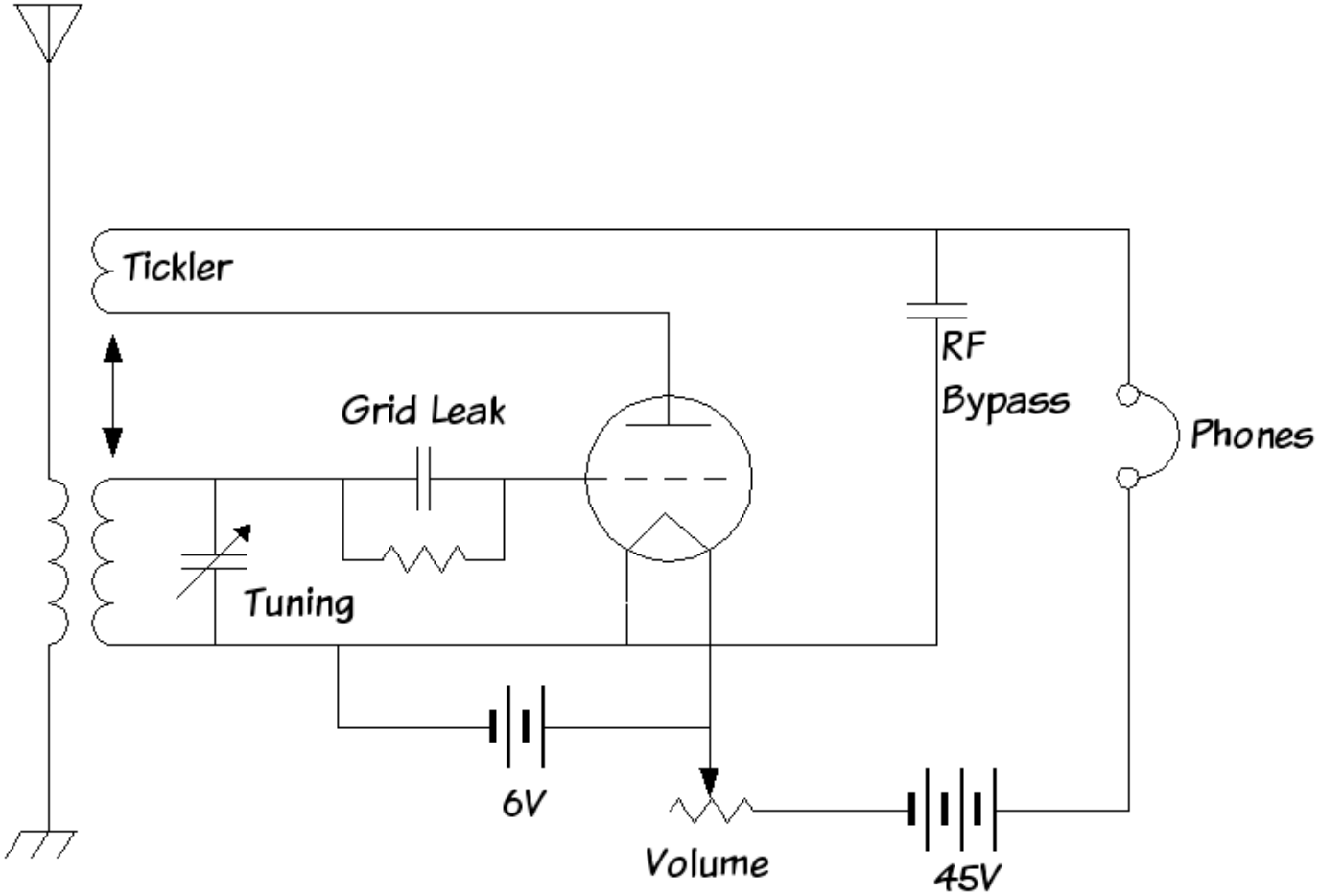
Armstrong, in 1912, took the amplified signal from the plate output of the triode and fed some of it back to the grid, input. He thereby "regenerated" the detected signal for high gain.

This permitted world wide reception of radio signals with simple, small radios.

De Forest won the patent fight about feed-back and oscillation, to the dismay of many radio engineers. Armstrong, however, may have adapted a 1911 sea-going radio operators' technique.

Armstrong also invented the superheterodyne circuit (with some help from the French), frequency modulation and super-regeneration.

Basic Regeneration Circuit



Constructed Triode Regenerative Receiver, providing world-wide reception of signals.

The Triode as Oscillator

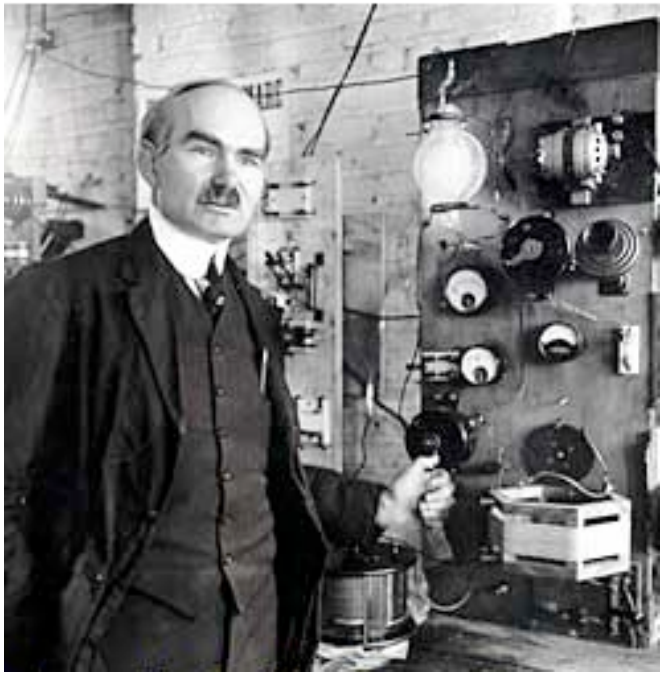
- Regeneration reaches the limit of oscillation, the creation of alternating current, ideally a sine wave.
- An alternating electric current can release its power as electromagnetic waves radiating from a tuned antenna.
- At frequencies above 10 kiloHertz, to many gigaHertz, these oscillations can be usefully modulated and transmitted as “radio waves,” to carry intelligence, including audio and video, just as spark signals carried Morse code in the earliest wireless days.

An Oscillating Triode in a de Forest Radio Transmitter, as early as 1915

Lee de Forest called himself the Father of Radio.

He was the first to broadcast a program of music, in 1908 (using an arc).

He was one of the first to broadcast using amplitude modulation of a carrier wave created by a vacuum tube, in 1915.



De Forest posing in 1950 with his 1920 "Oscillion" radio transmitter, used in 1916 to broadcast election returns. De Forest in 1920 in San Francisco and then Berkeley set up one of the first post WWI broadcasting stations (callsign 6XA).

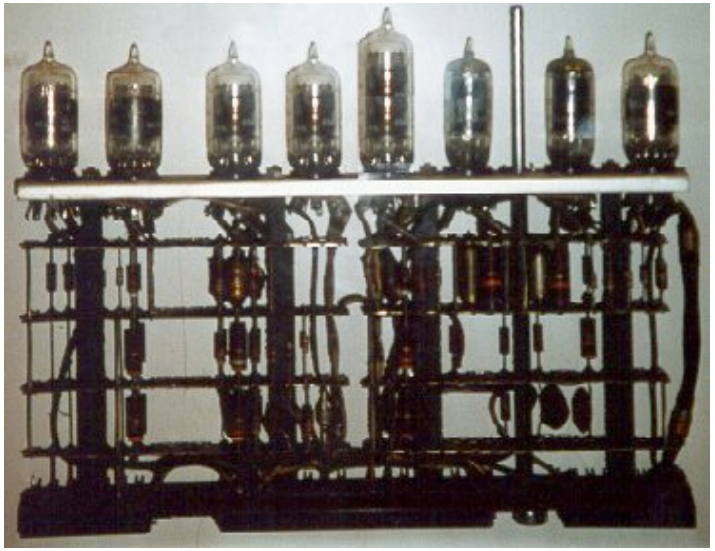
Photo from a de Forest website biography http://chem.ch.huji.ac.il/history/deforest.htm

Vacuum Tubes in Entertainment, Industry, War and Medicine

- Vacuum tubes provided the high frequency oscillations for radio and the television broadcasting, and the first television camera tube was Phil Farnsworth's Image Dissector invented in San Francisco in 1927 .
- These tubes provided audio and radio frequency amplification and oscillation for telephones, communications and entertainment.
- In World War Two, vacuum tubes enabled RADAR and the artillery proximity fuse, and cryptology, all essential to victory.
- They controlled industrial processes of automation and otherwise enabled instrumentation and control.
- They provided heating radiation for medicine (diathermy) and industry – and then convenient cooking.

Vacuum Tubes Enabled Computers

- The largest computers based on vacuum tubes had racks and racks of tubes filling large rooms.



IBM 701 vacuum tube circuit block, 1952, 4,000 tubes used

ENIAC, 1940s, first used for ballistics calculations

Back to the Future

- The crystal detectors of the wireless era were semi-conductors (as was the Fleming valve), but solid state, requiring no filaments.
- Silicon crystal mixers simplified WW II RADAR circuits.
- Bell Labs in 1947, relying on the earlier work of other inventors, invented the amplifying transistor.
- The transistor could also act as a switch in digital circuits.
- Transistors and other circuit components could be fabricated on silicon chips, miniaturizing devices.
- The vacuum tube is now, therefore, largely of historical interest, except for very high power applications.
- Nonetheless, “Real Radios Glow in the Dark.” ##

Venue Diploma