

# **Edwin Armstrong and the Dawn of the Electronic Age**

Al Klase – N3FRQ

The Radio Technology Museum

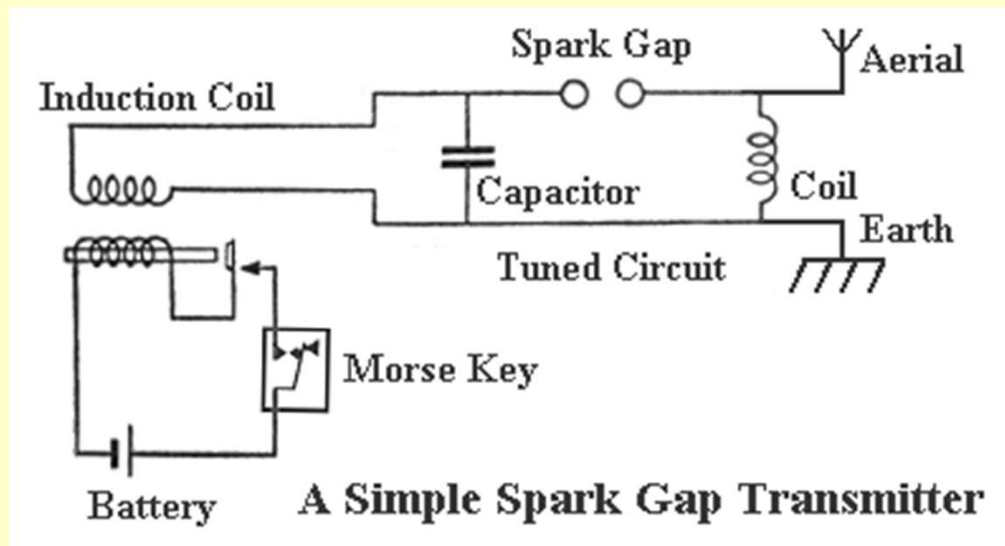
At InfoAge

# The State of the Art - 1912

- No practical amplifiers
- Radio
  - Morse code only
  - Passive receivers: All the energy that got to your eardrum came from the transmitter.
- Telephone
  - Users often did not use their own phone for long - distance calls, but made an appointment to use a special telephone booth or "silence cabinet"
- Computing – All mechanical

# Damped-Wave Transmission

- Spark Transmitter
  - Heinrich Hertz -> Marconi
  - The only game in town!



# Damped-Wave Reception

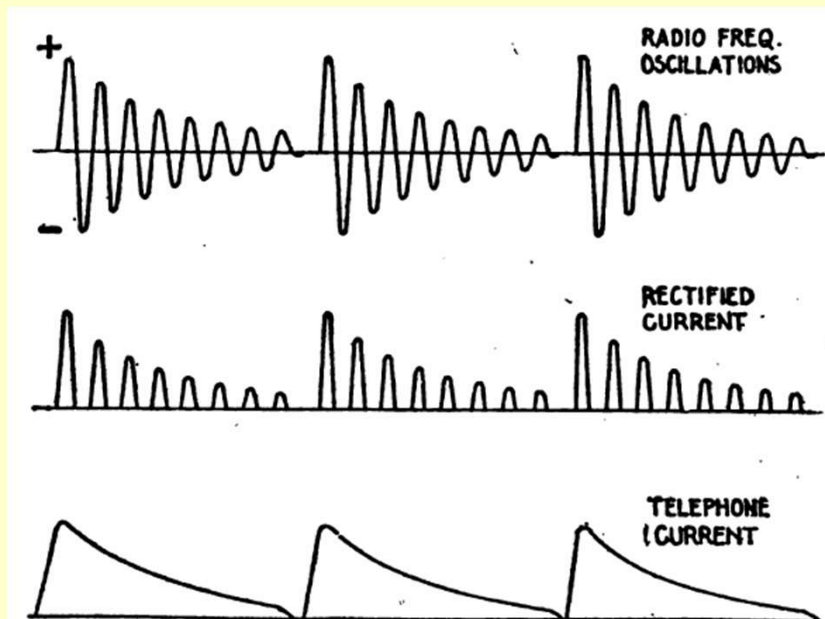
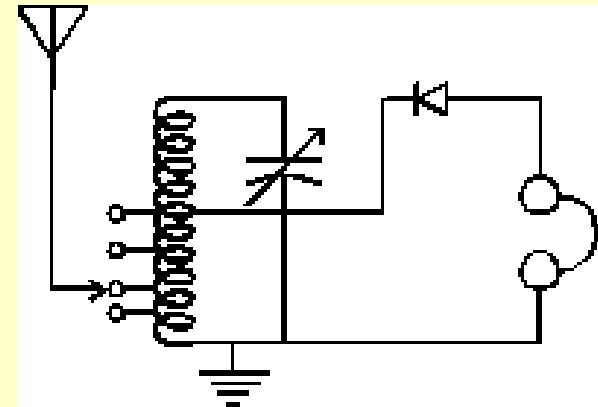
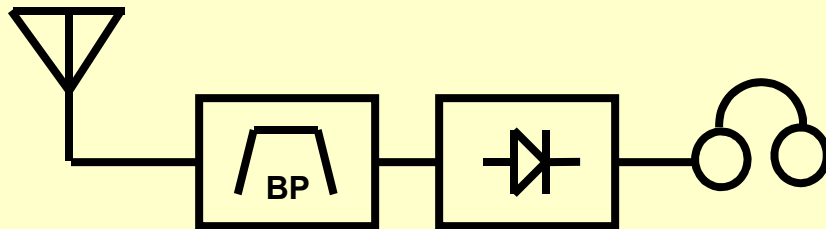


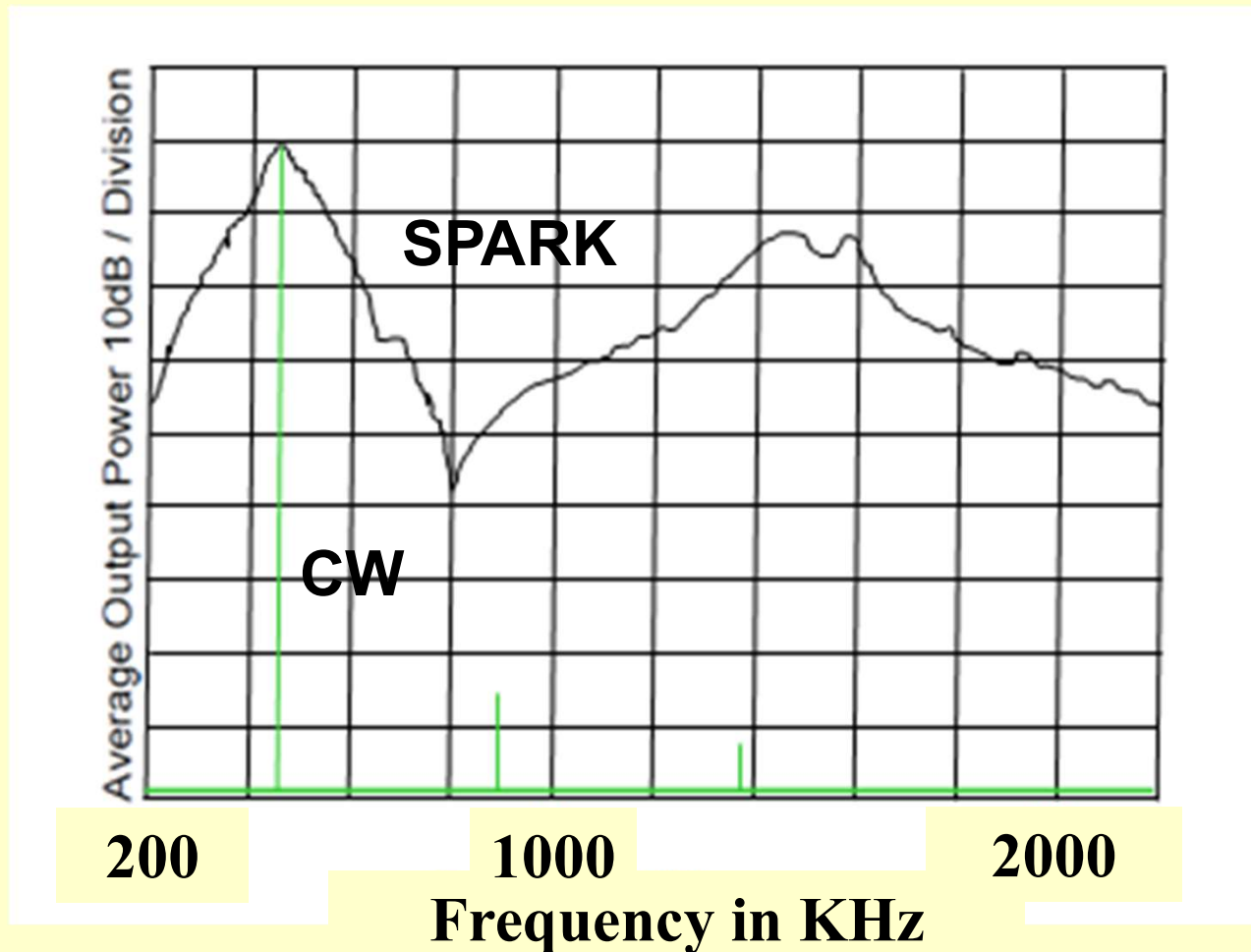
Fig. 148a, b, c—Showing how Incoming Oscillations are converted to Direct Current Pulses.



IP203 Triple Radio Crystal Detector<sub>4</sub>  
by Wireless Specialty Apparatus

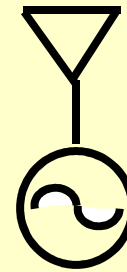
# Continuous-Wave Telegraphy

- Pure sine wave (one discrete frequency)

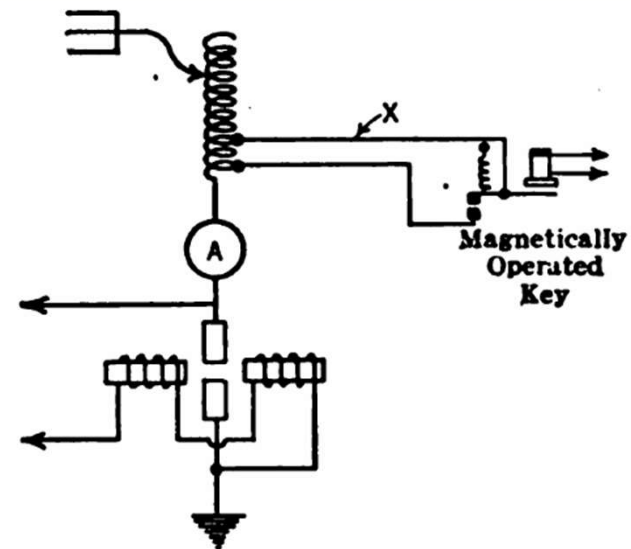


# Continuous-Wave Telegraphy

- Reginald Fessenden ca. 1902-1906
  - Alexanderson Alternator
  - On-Off keying
- Vladimir Poulsen – Poulsen Arc - ca. 1909
  - Frequency-Shift Keying



**1000 Volts DC**



# Continuous-Wave Heterodyne Reception

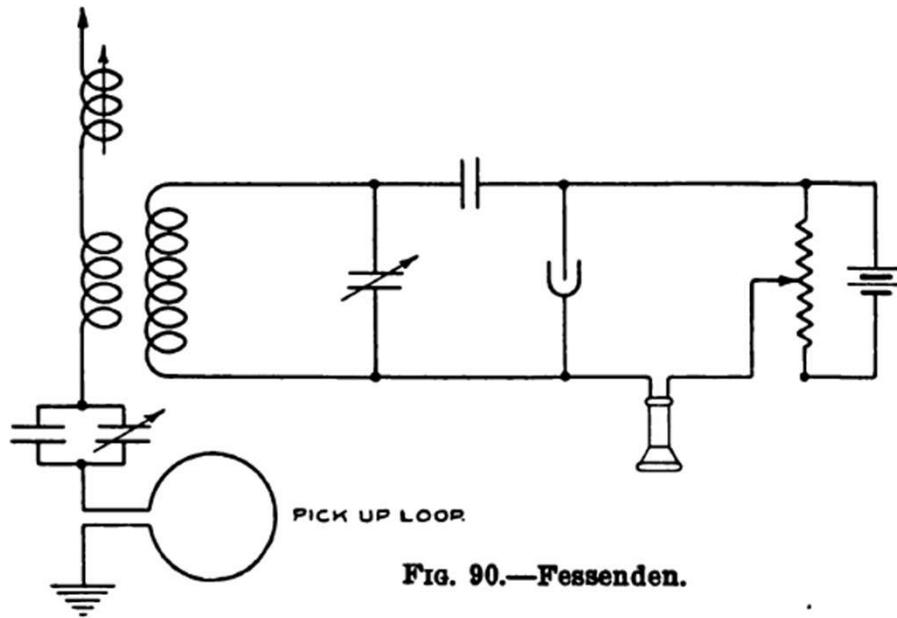


FIG. 90.—Fessenden.

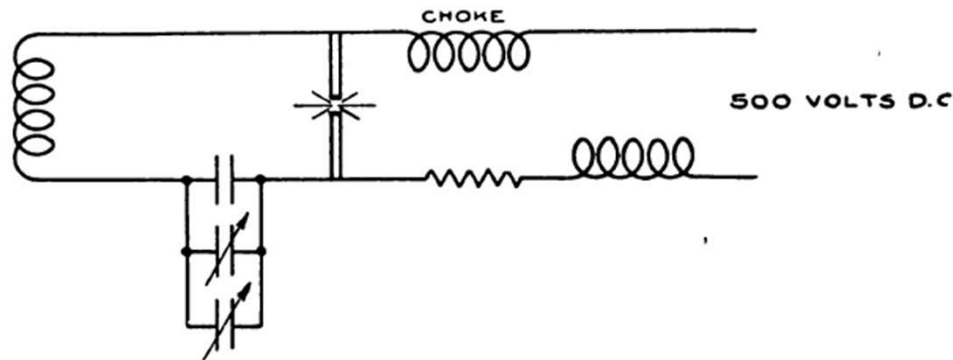
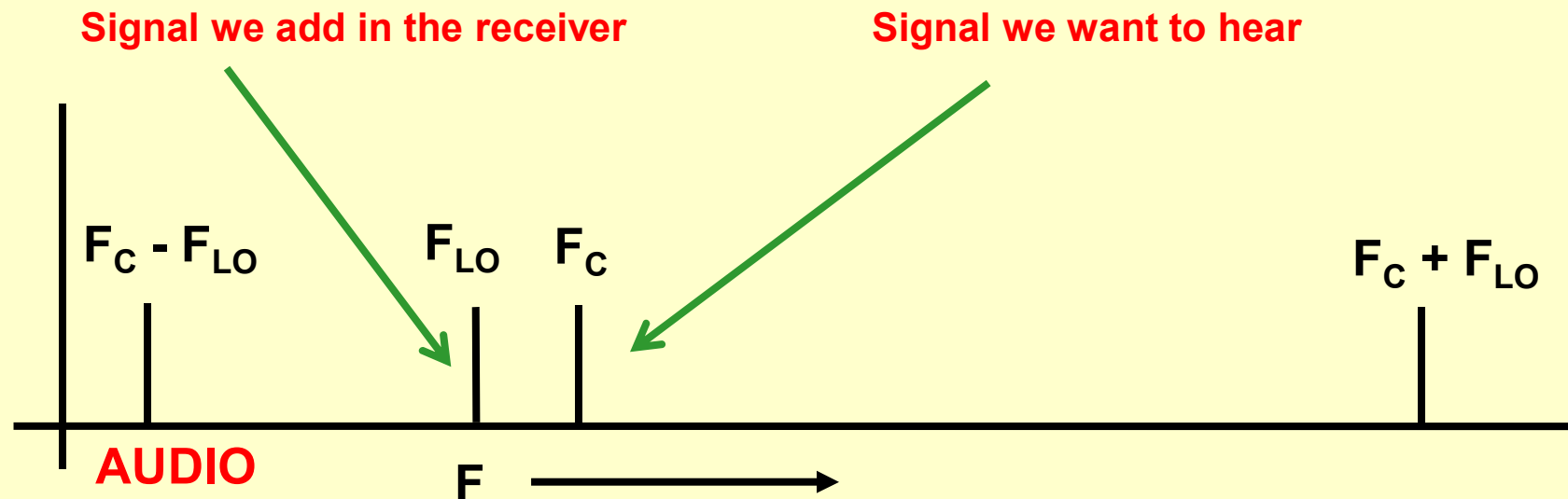


FIG. 91.—Fessenden Heterodyne.

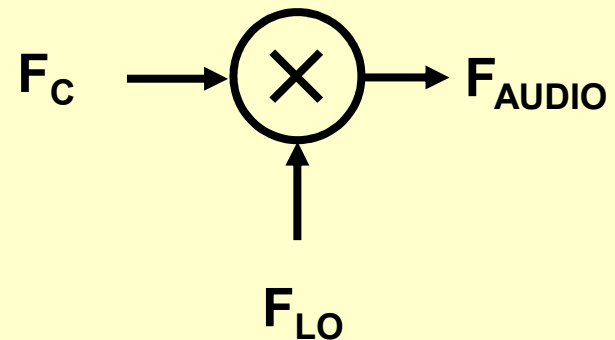


Professor  
Reginald Aubrey Fessenden

# Heterodyne Reception (Beat Notes)



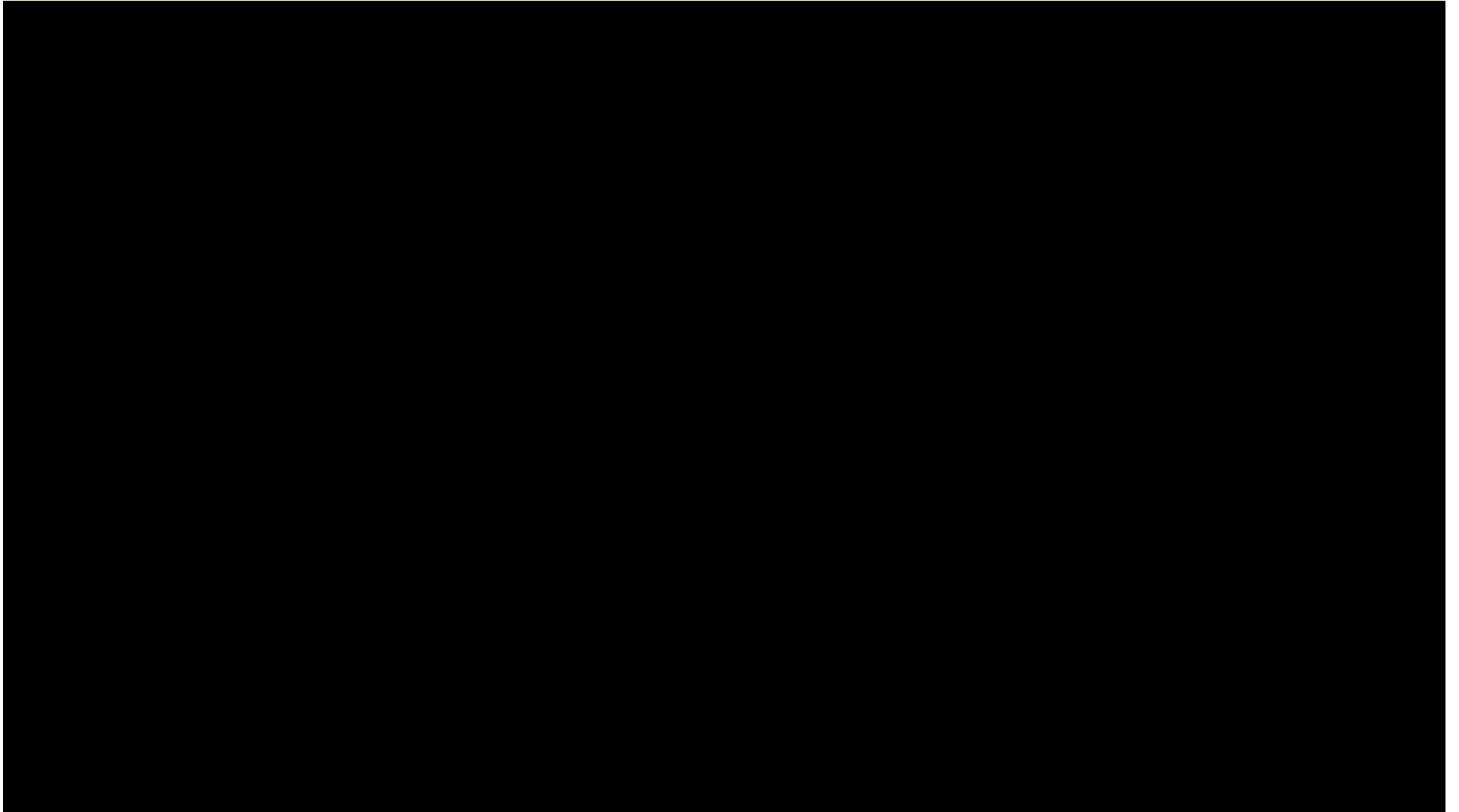
For example:  
Continuous wave carrier,  $F_C$ , at 1000KHz  
Local oscillator, LO, at 999KHz  
Audio output at 1KHz



Let's see and hear how this works.



# RF Beat Notes



# Continuous-Wave Reception

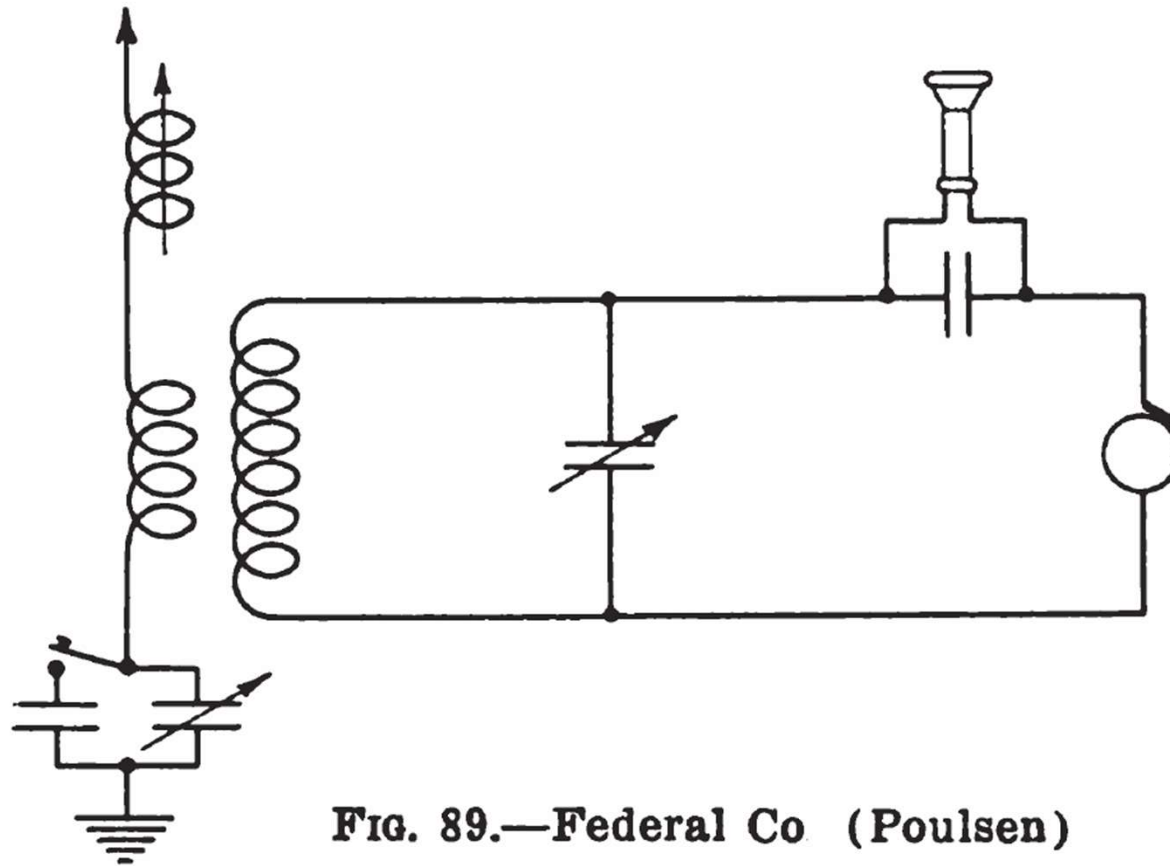
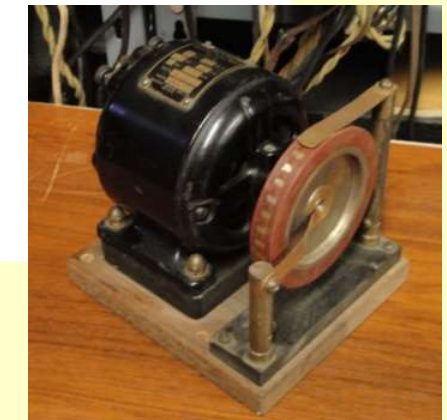
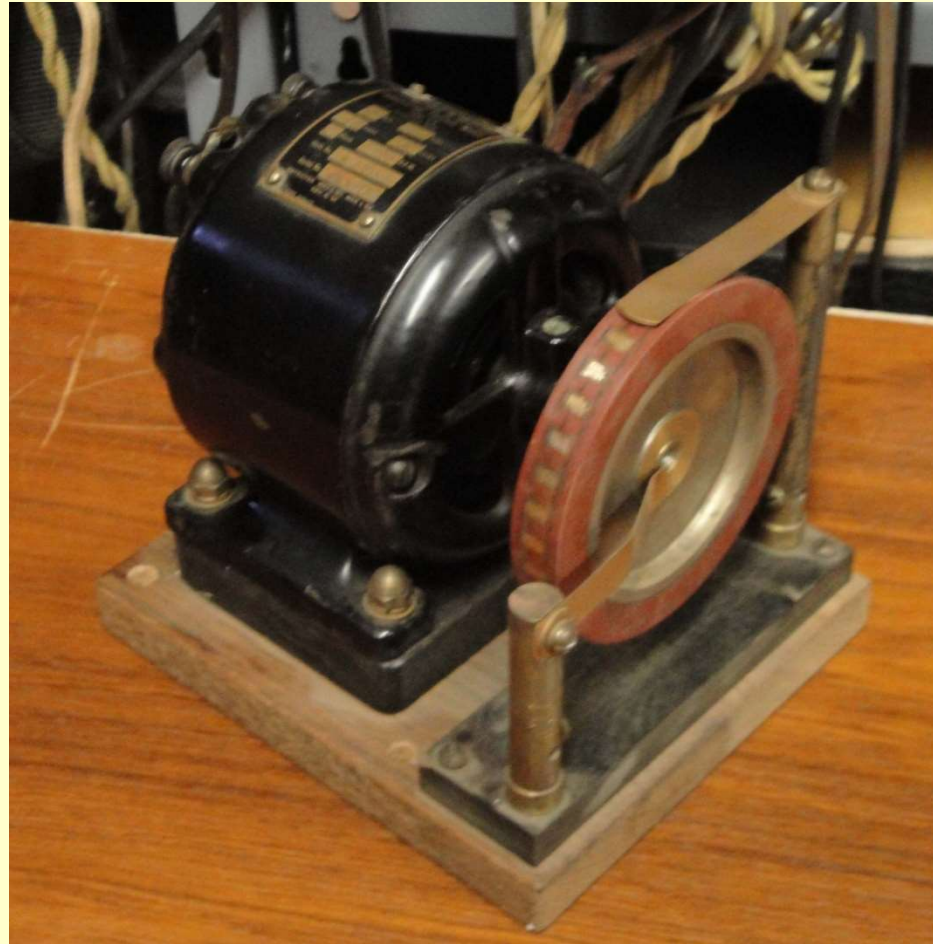


FIG. 89.—Federal Co (Poulsen)



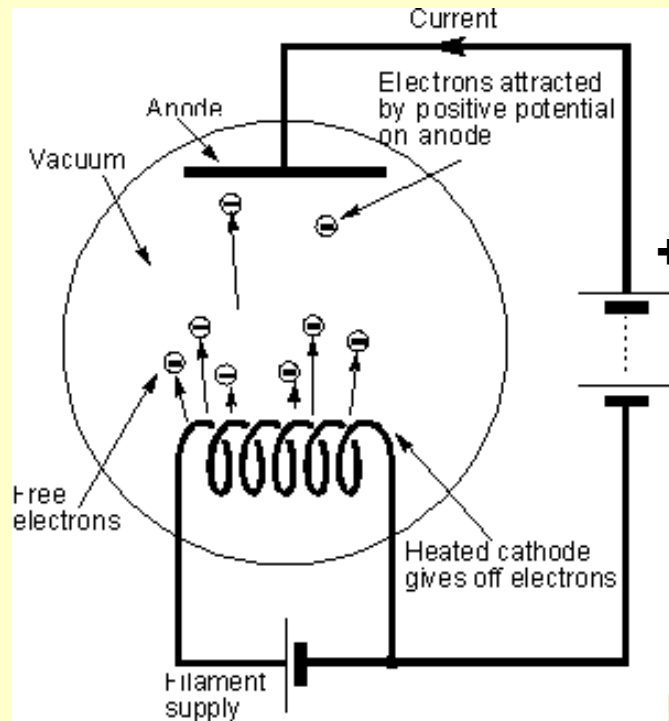
# Sound of the Tikker



# No Amplification

- Both the Fessenden and Poulsen systems employed passive receivers.
- All the power that reached the listeners eardrum came from the transmitter.

# The Edison Effect and The Fleming Valve



(Thomas Edison 1880)

1904



Sir John Ambrose Fleming  
1849 – 1945



# The Audion



Lee DeForest

1873 - 1971

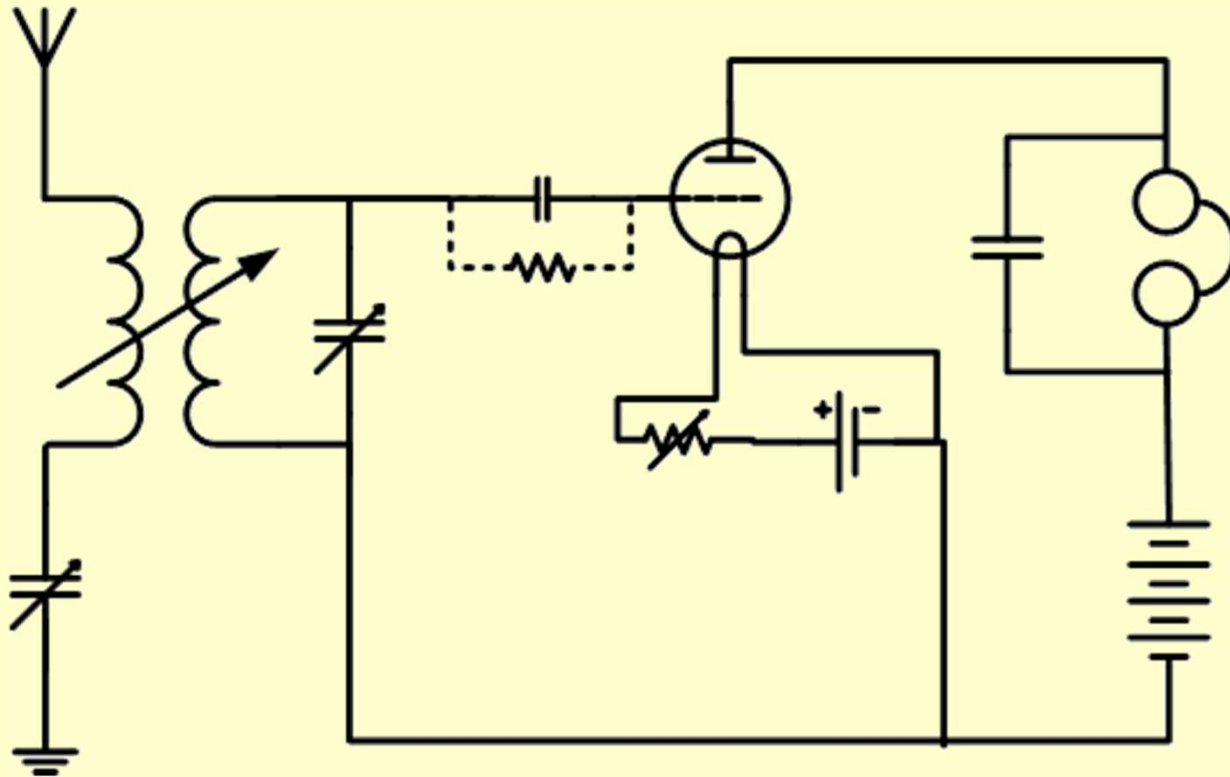


1906





# Armstrong's Experimentation 1912

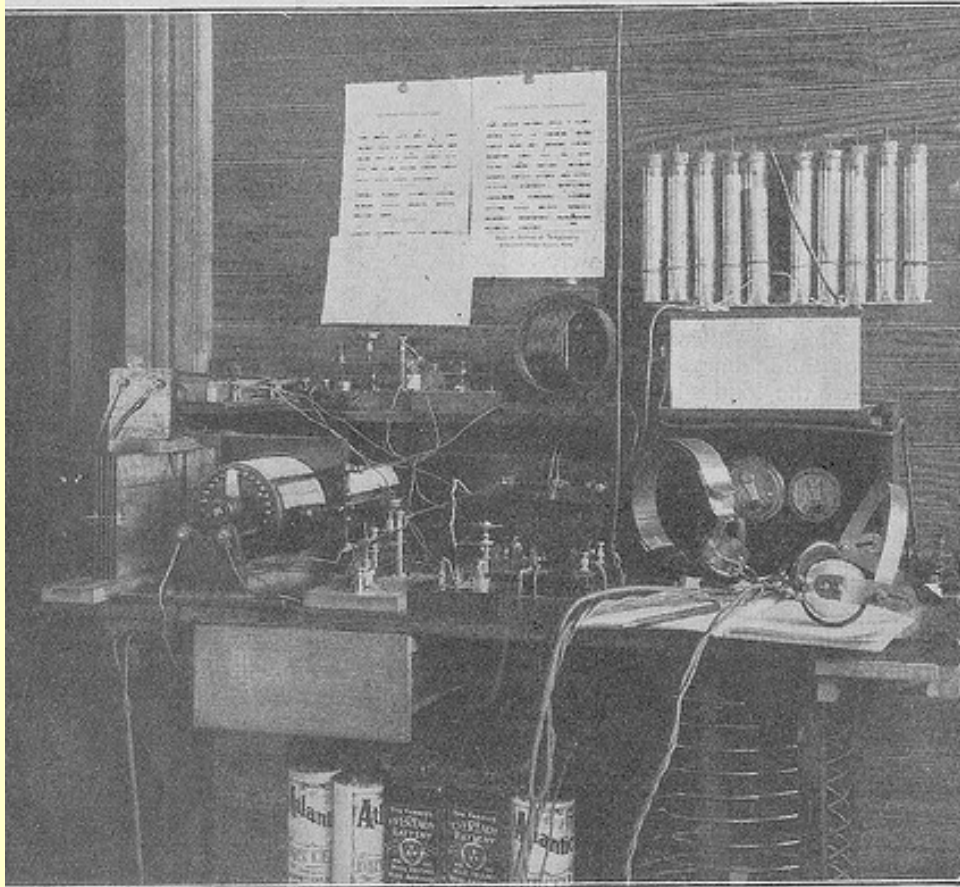


**The original DeForest circuit**

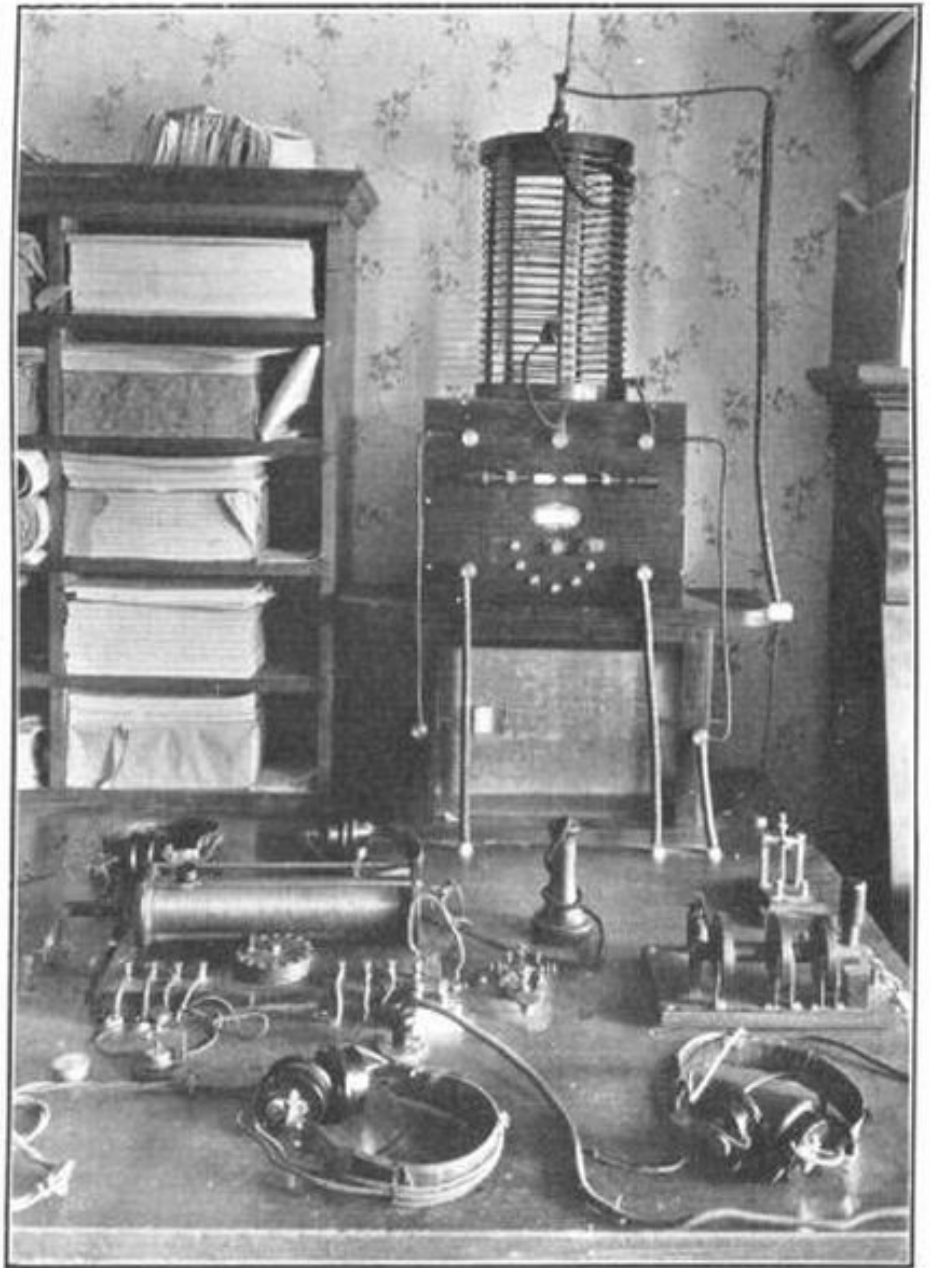


Photoshop by Steve Klose

# Radio in 1912



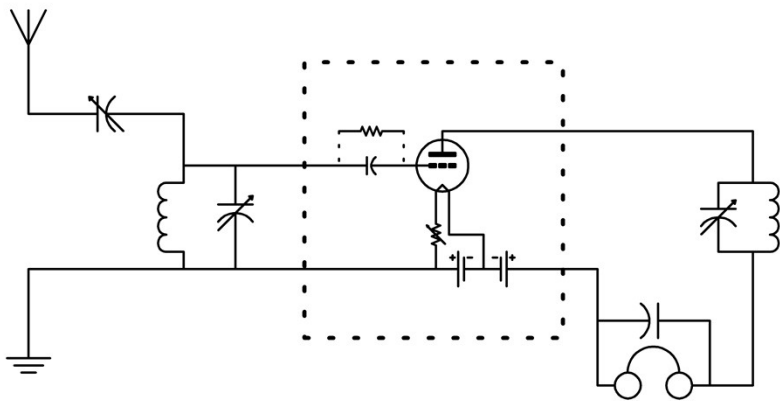
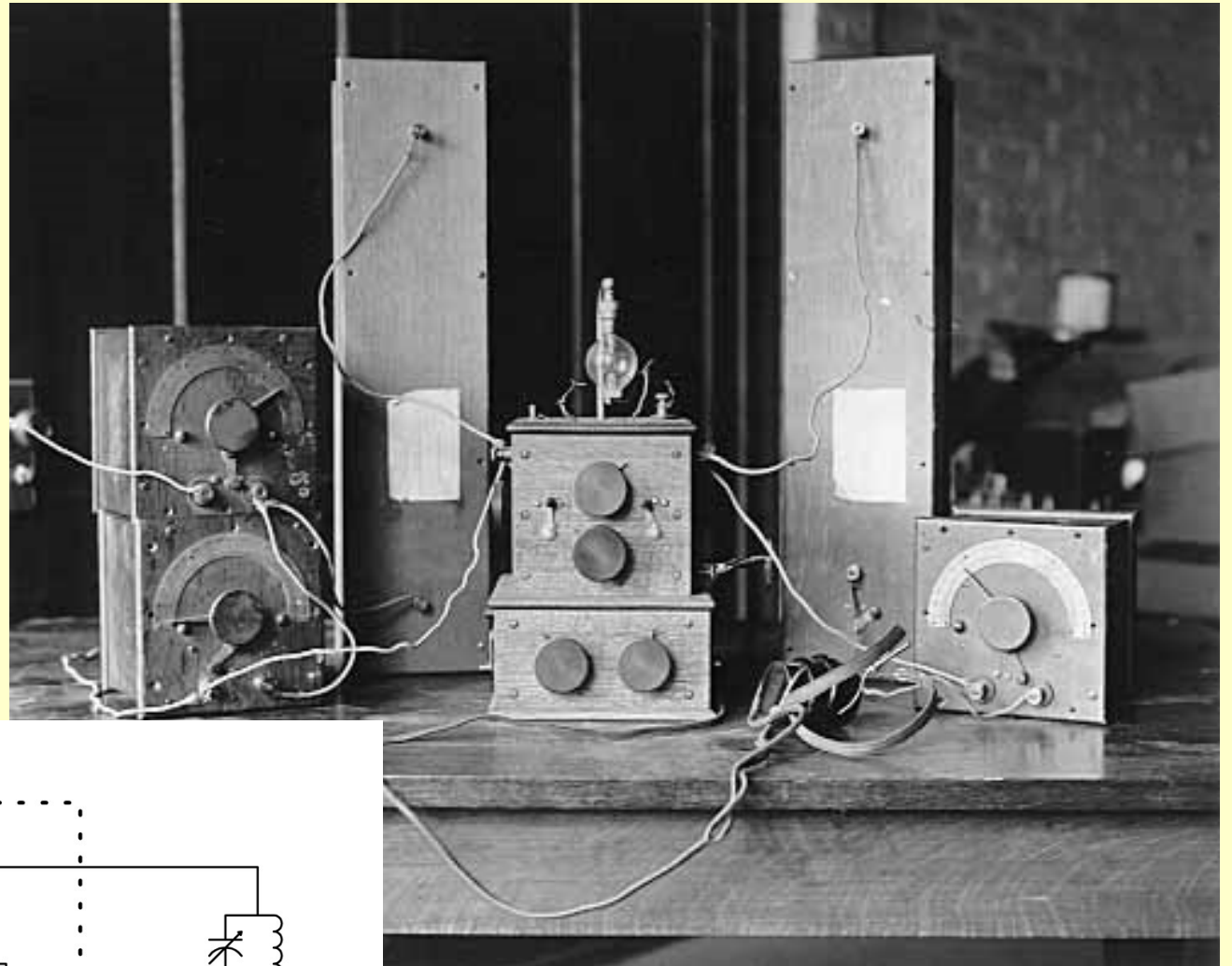
A typical amateur station of the 1912 type. Note the numerous detectors and the variable capacitor on the extreme left. The glass tubes on the wall constituted the high tension sending coils.



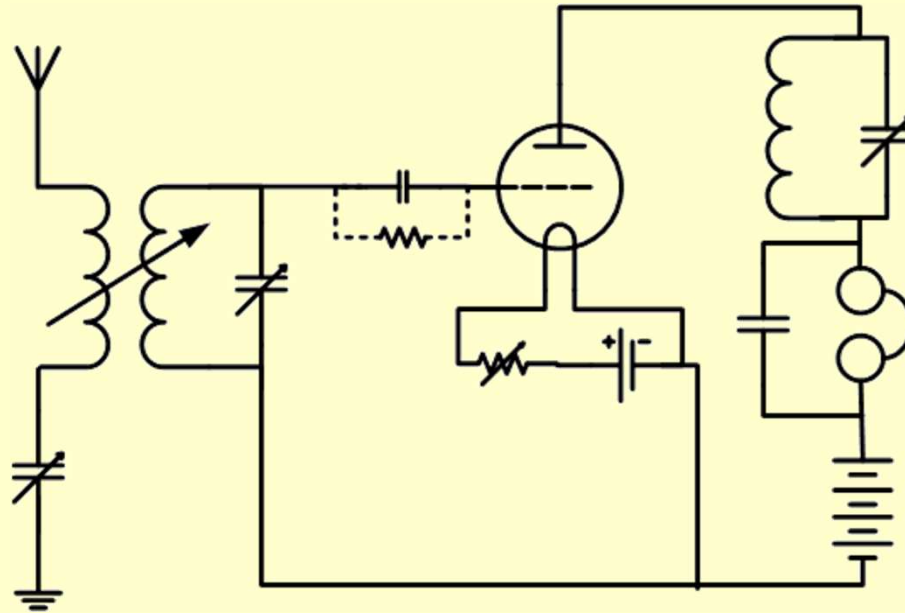
**Plate XII.** Photograph of station of the Southern Pacific Telegraph School, 542 Central Ave. Apparatus made by a Los Angeles boy.



# Regen Patent Model?



# Armstrong Experimentation



“All the old timers remember CC, later known as MCC and WCC, the Marconi press station at Wellfleet, Mass. This station was the one-hundred percent reliable testing standby of all experimenters, and on MCC the first tests were made. A standard audion detector system was set up and tuned in, and a tuning inductance introduced into the plate circuit of the audion.”

THE REGENERATIVE CIRCUIT

by Edwin H. Armstrong

THE ELECTRIC JOURNAL. Vol. XVIII, No. 4, April 1921

# 22 SEP 1912 - Regeneration!

“Then various things began to happen. As the plate inductance was increased, the signals were boosted in strength to an intensity unbelievable for those days, the more inductance the louder the signal, until suddenly the characteristic tone of M. C. C. -- the tone which any of the old timers, if they heard it on Judgment Morn, would recognize instantly -- disappeared, and in its place was a loud hissing tone, undeniably the same station, but recognizable only by the characteristic swing and the messages transmitted.

A slight reduction of the plate Inductance and the old tone was back again, -- and then the placing of the hand near a tuning condenser, and the hissing tone reappeared.

It required no particular mental effort to realize that here was a fundamentally new phenomenon, as obscure as the principle of the operation of the audion itself, but which opened up an entirely new field of practical operation.”

**Hear what Howard heard.**

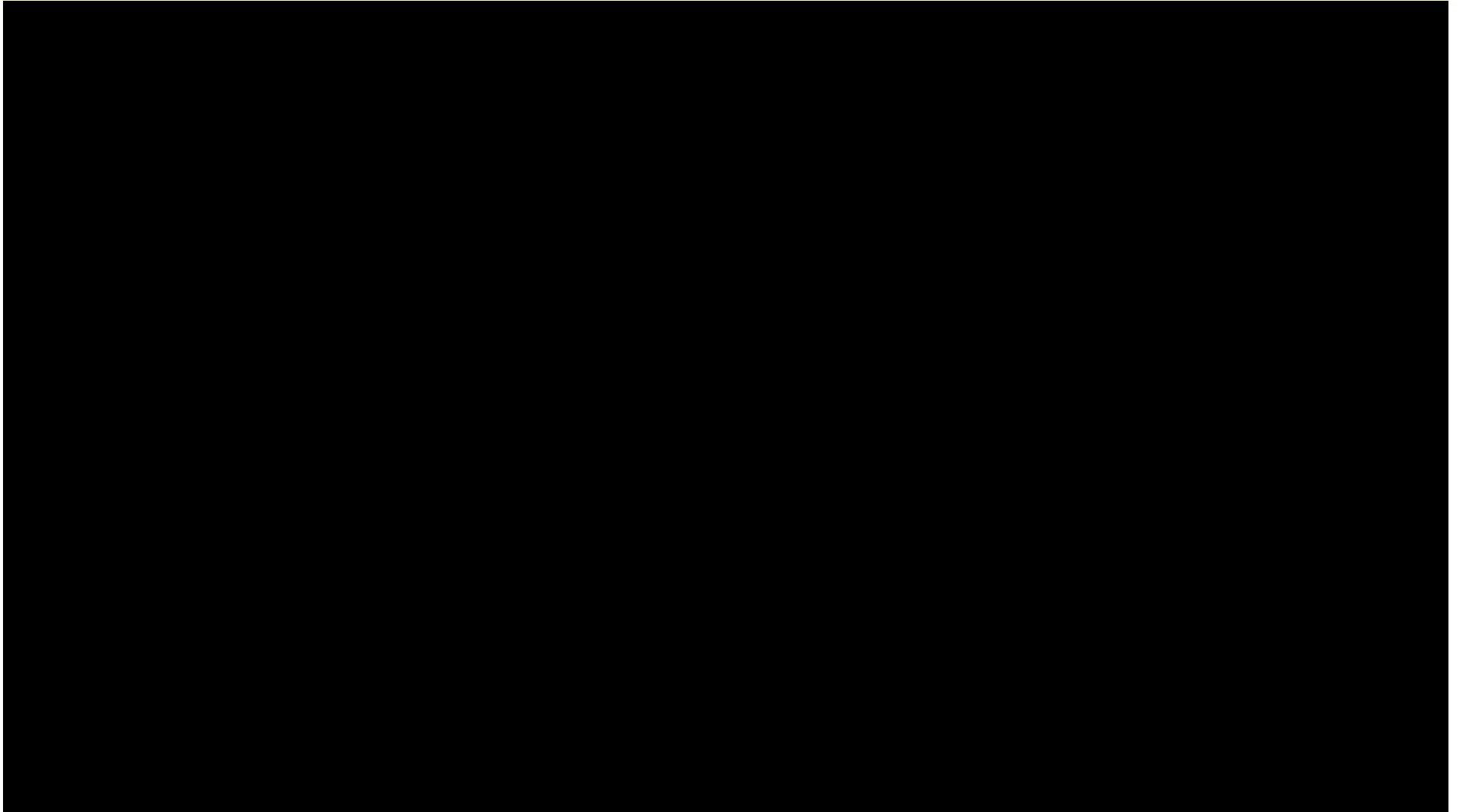
**Great amplification obtained at once!**

**22 SEP 1912**

## Dec 1912

- Noticed beat notes on CW signals
- Tones in place of buzzes.

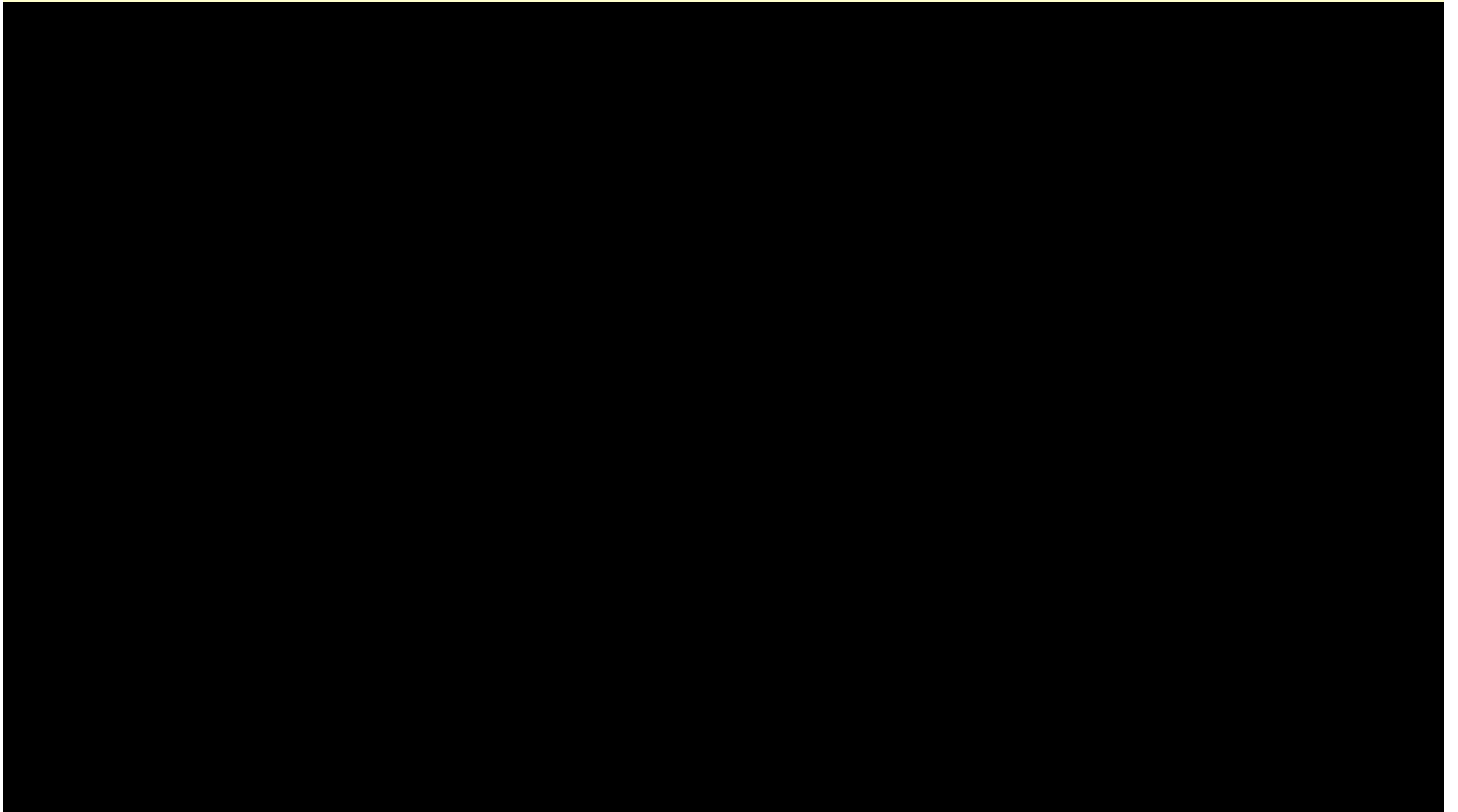
# Continuous-Wave Reception



## **Jan – Feb 1913**

- Observed hand-capacitance tuning suggesting oscillation.

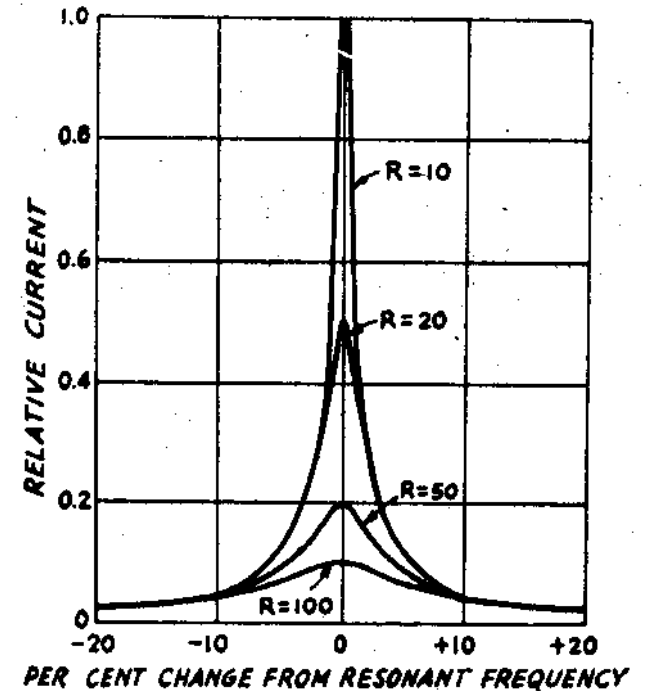
# Hand Capacitance





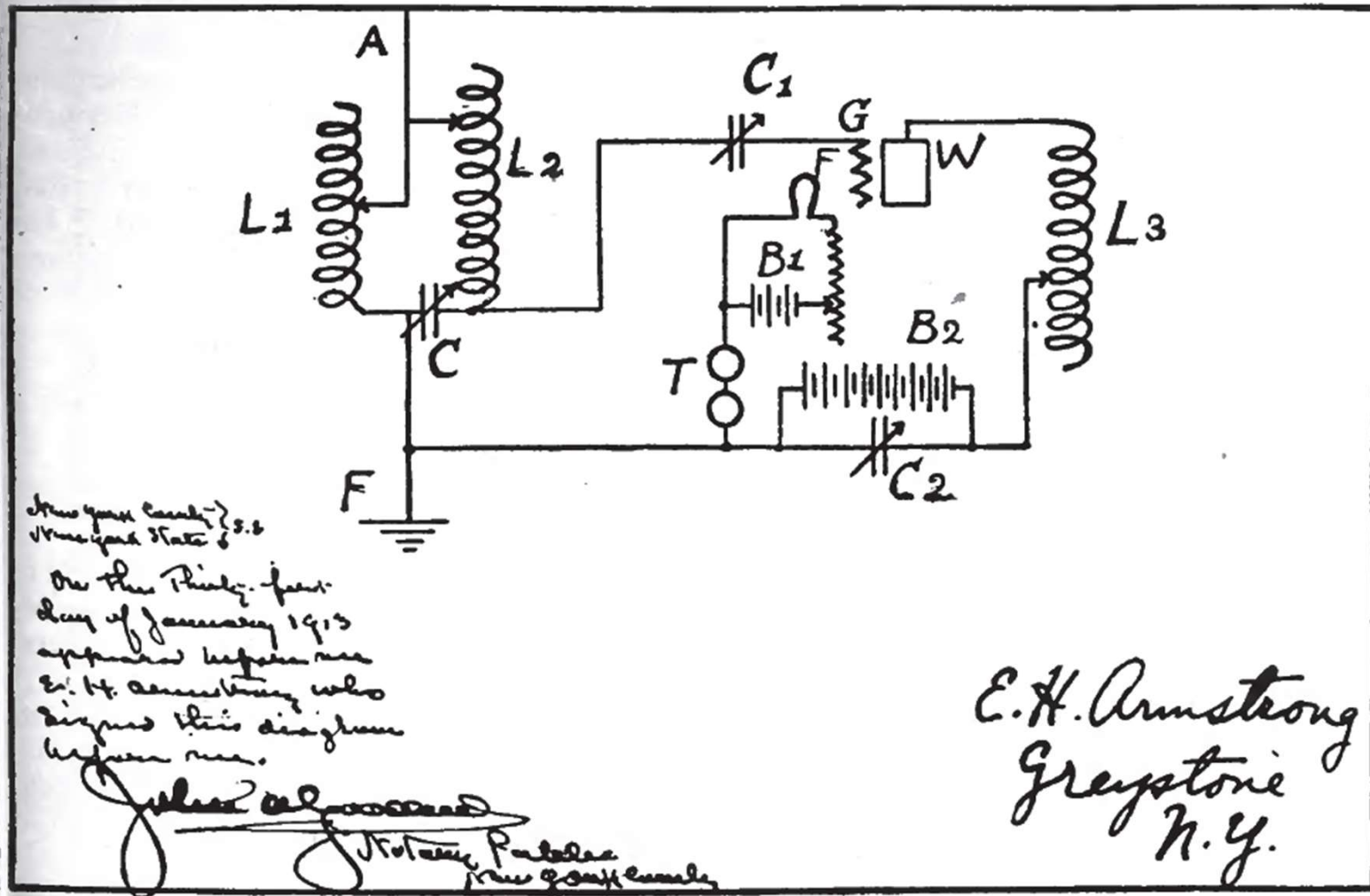
# Modes of Operation

- Regenerative (not oscillating)
  - Improved sensitivity
  - Improved selectivity
  - Square-law response
- Autodyne (oscillating)
  - BFO function for CW or SSB
  - A.k.a., Direct Conversion
  - Linear response



# 31 JAN 1913 – Notarized Drawing

THE ORIGINAL DRAWING OF THE FEED-BACK CIRCUIT WHICH  
LARGELY DETERMINED THE COURT IN ARMSTRONG'S FAVOR



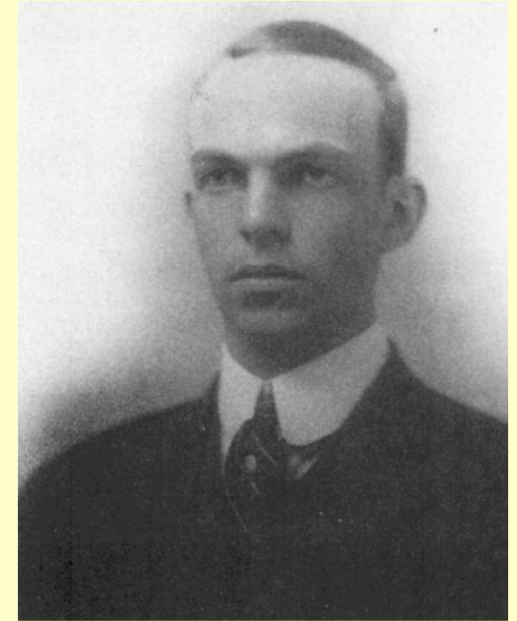
# March 1913

- March 1913 – Demonstrated oscillation at his home in Yonkers to Professor Frank Mason using a second Audion.

## Late Spring 1913

- Demo to Morton Arendt, instructor in electrical engineering, Columbia University, at Armstrong's home.
- Armstrong was “only interested in receivers”

# June 1913



- Graduated from Columbia.
- Became assistant to Morton Arendt and Walter Schlichter.
  - Taught Navy Radio Class
- John Armstrong put up money for patent.

# Fall 1913

- Set up antenna at Columbia
- Patent filed. “Receiving Systems” - 29 Oct
- Demo to Morecroft and Pupin
- Demo to DeForest
  - Receiver hidden in a box.
  - Box in a different room than Deforest

# DEC 1913

- 18 DEC 1913 – Filed transmitter patent
- Demo to Marconi personnel at Columbia

# 30-31 Jan 1914

- Demonstration to Marconi America at Belmar, NJ
  - David Sarnoff and Roy Weagant
  - Edwin Armstrong and John H. Morecroft





# Stations Heard

- Spark Stations – much louder on Armstrong's set
  - Glace Bay Nova Scotia
  - Clifden Ireland
- Continuous-Wave Stations – inaudible on Marconi radio
  - Nauen, Germany
    - Slaby-Arco alternator
    - ON-OFF keying
  - San Francisco and Honolulu
    - Poulsen Arc transmitter
    - Frequency-shift keying

# David Sarnoff's Report



.....In conclusion I would state that the results obtained with Mr. Armstrong's receiver are sufficiently convincing to warrant our most careful investigation of his patents and circuits, etc., for I believe that his device has tremendous advantages and unless there be other systems of equal merits, which are unknown to me, I am of the opinion that he has **the most remarkable receiving system in existence.**



## Roy Weagant's Report

.....It is my opinion, based on the result of these tests, that Mr. Armstrong, has a system of an enormous practicable value, and that the results obtained Friday night, were so far in advance of anything possible with our present methods, that **it constitutes a new era in the art of wireless signaling** . In addition to the tremendous sensitiveness of this apparatus, the following exceedingly important points were noticed:

1. It will work on either a spark transmitter or one emitting continuous oscillation .....

# AT&T

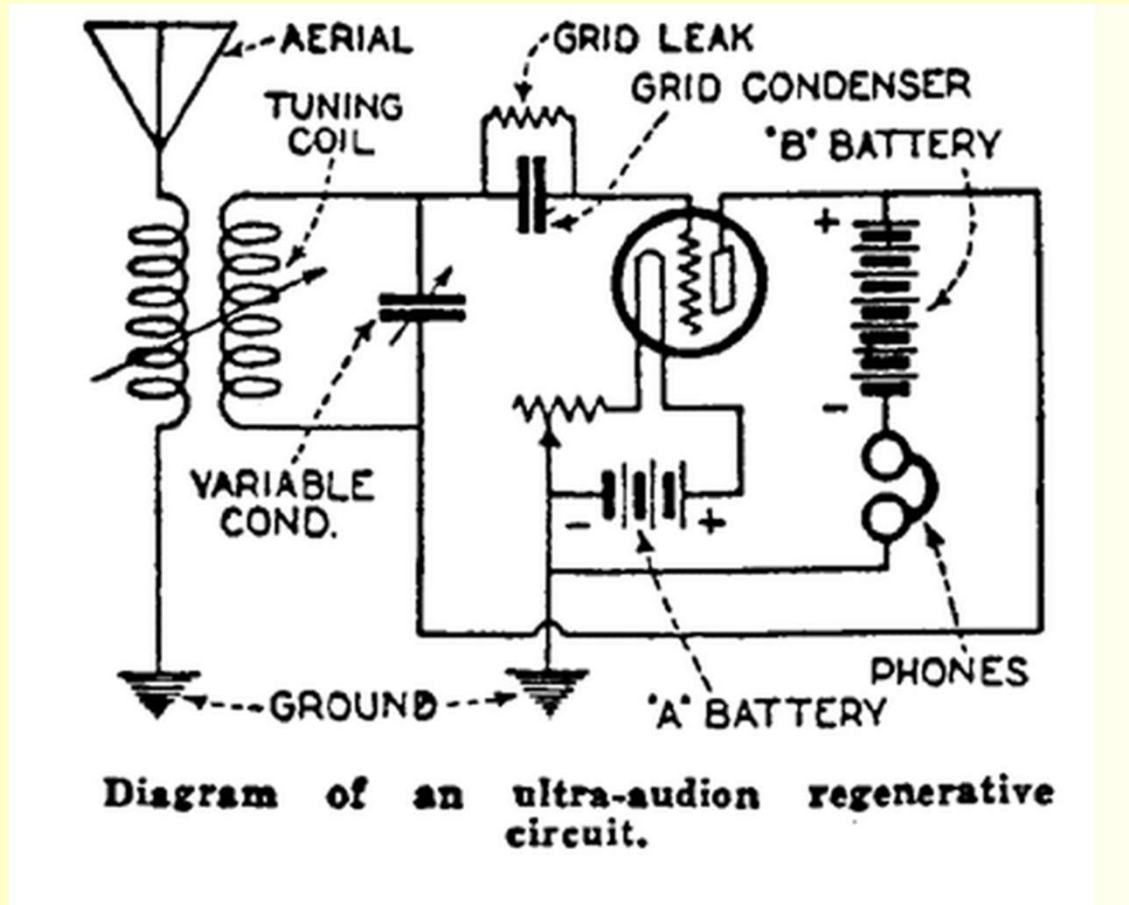
- **6 FEB 1914 – Demo to AT&T at Columbia**
  - J. J. Carty Chief Engineer
  - Bancroft Gherardi, Jr.
  - Dr. F .B. Jewett
  - Lloyd Espenschied
- **Carty re: Poulsen arc signals**
  - "It sounds like an 'inebriated' ,flute player"
- **Spring 1914 – formal disclosure to AT&T**

# So, what happened?

- **Marconi**
  - Using vacuum tubes (diodes) “Fleming Valve”
  - Already in litigation with DeForest
  - WWI starts later in 1914
- **AT&T**
  - Working with Audions for telephone repeaters since 1912
  - “Goes silent” after Armstrong’s disclosure.
- **Deforest**
  - Back to the drawing board

**One of the most important factors in development engineering is knowing that something is possible.**

# Deforest – “Ultraudion” Circuit



- First exhibited at a meeting of the American Physical Society in April 1914. (Howeth, Chapter XVII, -4)

# Deforest - Ultraudion

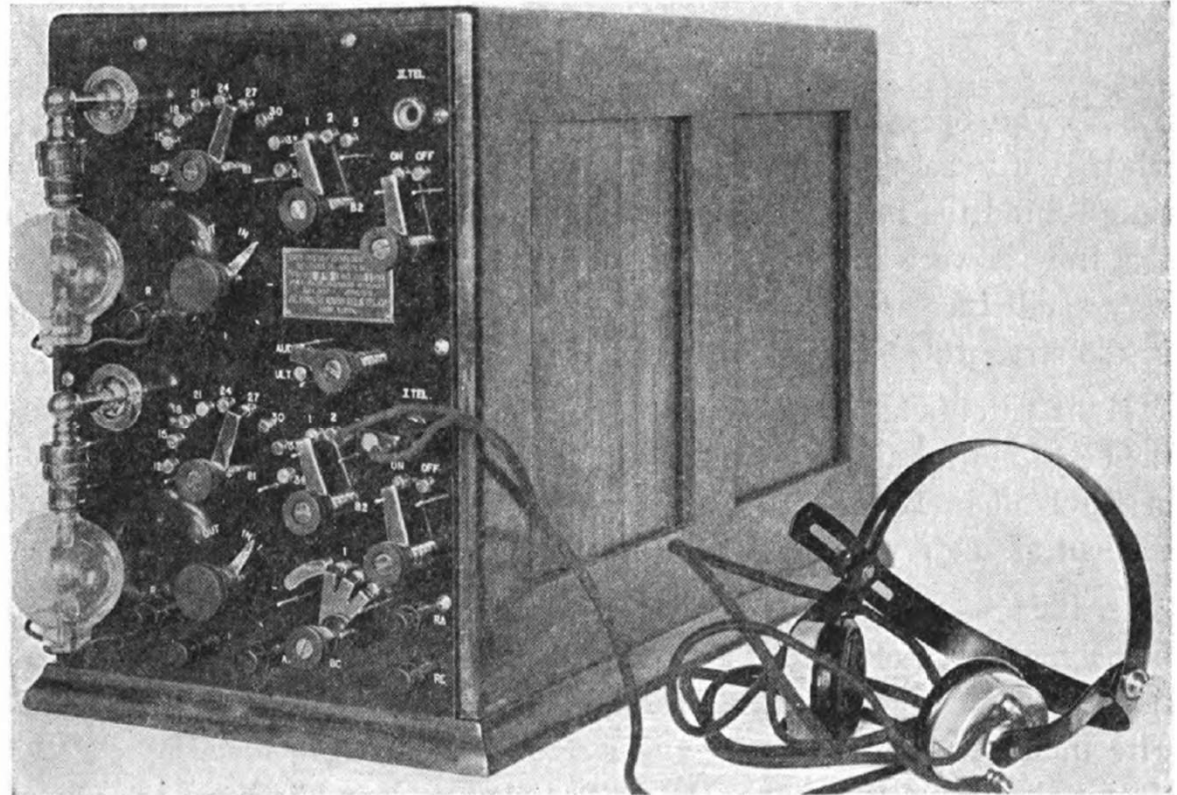


FIG. 92G.—DeForest Audion-Detector.

- From *Robinson's Manual of Radio Telegraphy and Telephony*

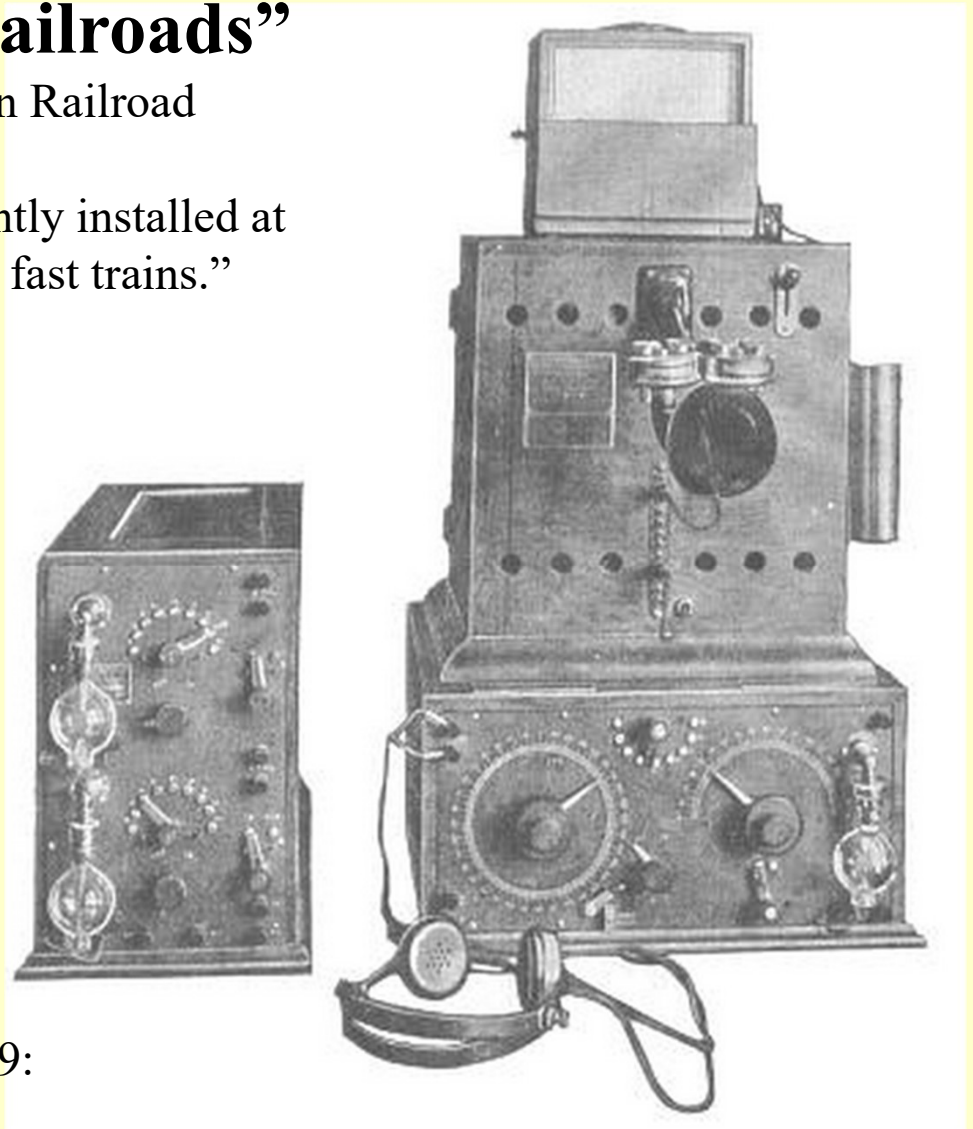


# Deforest – Radio Telephone

## “Radiotelephony for Railroads”

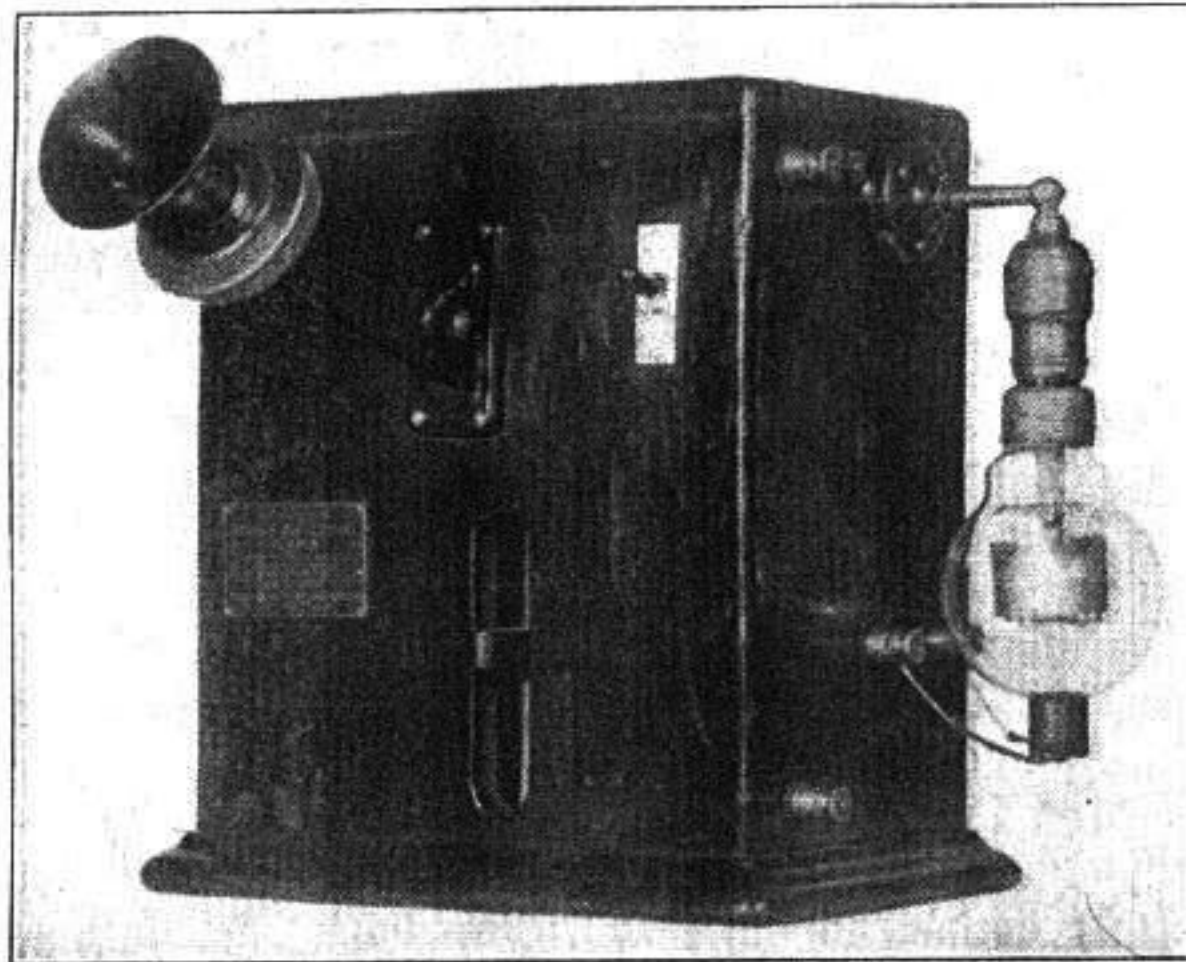
Delaware, Lackawanna & Western Railroad

“Wireless-telephone apparatus was recently installed at Scranton, Pa., and on one of the through fast trains.”



Electrical World, May 30, 1914, page 1269:

# Deforest – Radio Telephone

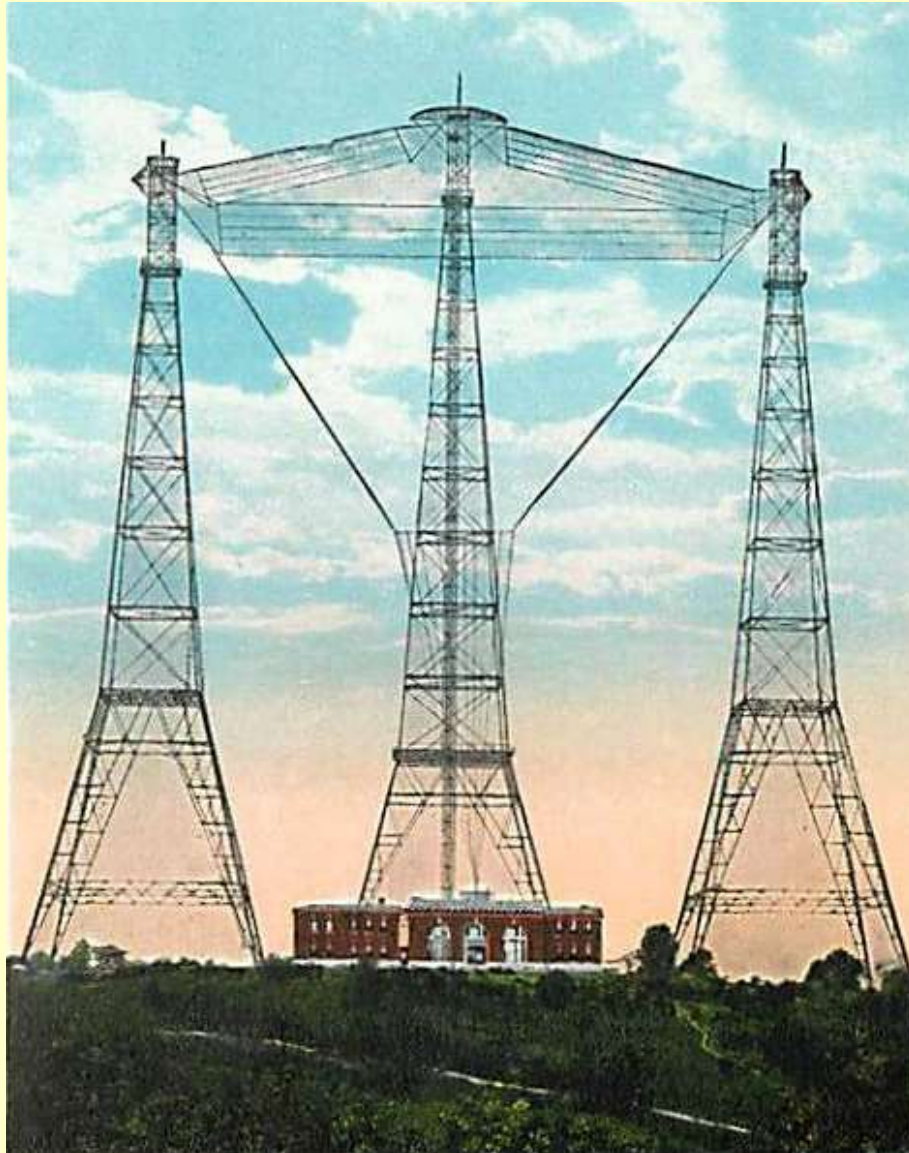


TRANSMITTING APPARATUS FOR RADIO TELEPHONE

**“Oscillion”**

*Electrical World*, July 18, 1914, page 144:

# U.S. Navy



# U.S. Navy High-Powered Chain

- Act of Congress of 22 August 1912 - Stations in Canal Zone, California , Hawaiian Islands, American Samoa, Guam, the Philippine Islands
- 1915 – Eliminated Guam and Samoa links as the result of improved, i.e. regenerative, receivers

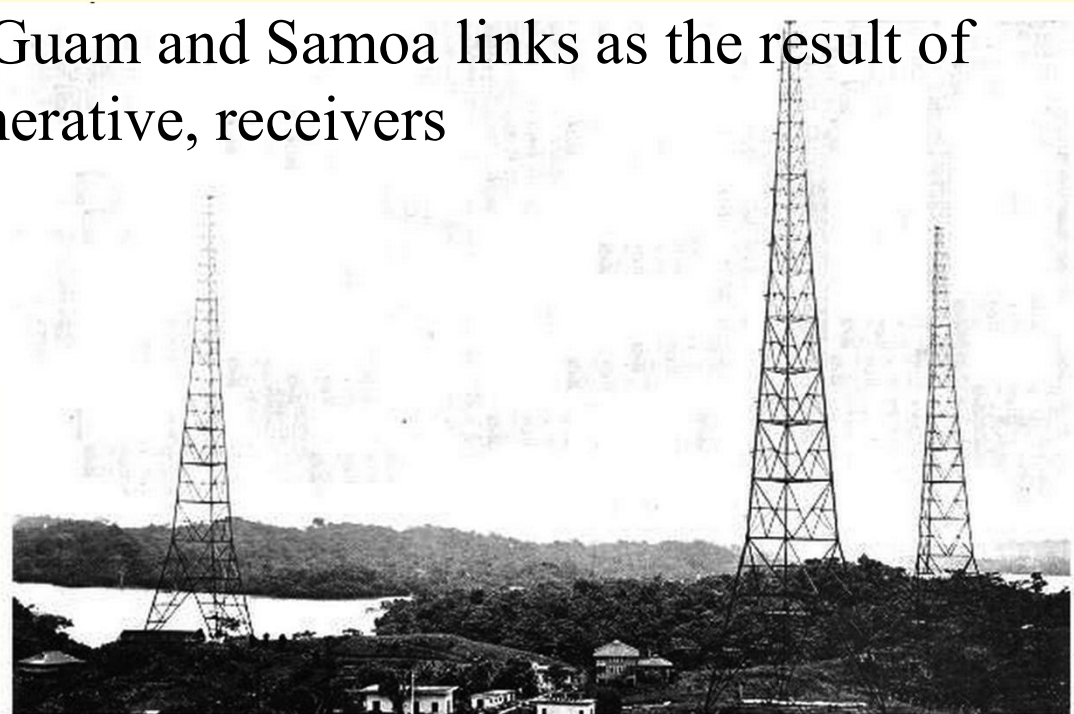


FIGURE 18-1. U.S. Naval Radio Station, Dairen, C.Z., 1915.



# U.S. Navy Typical Receiving Equipment

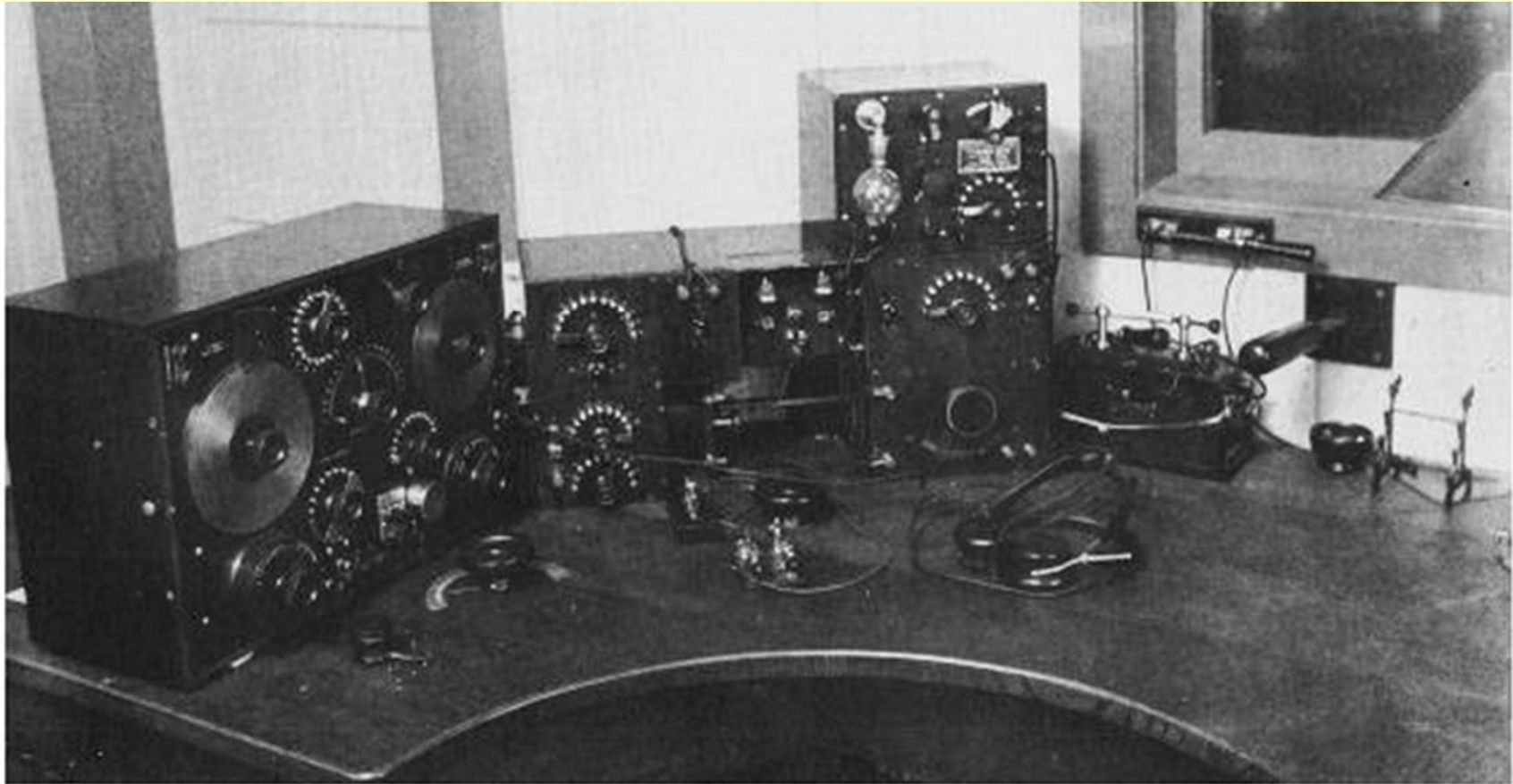


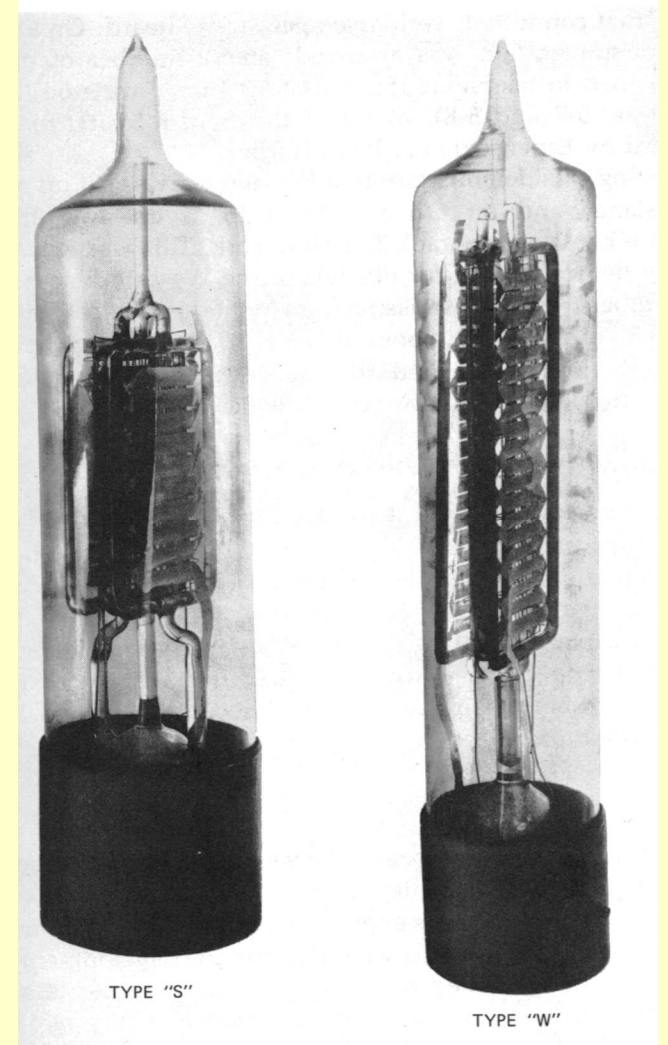
FIGURE 15-1. Typical receiving room installation, 1914—equipment, consisting of Type A (Cohen) receiver, Wireless Specialty Co. (IP76) receiver, crystal detector, ultraudion detector.

Howeth,

# Meanwhile, back at The Phone Company

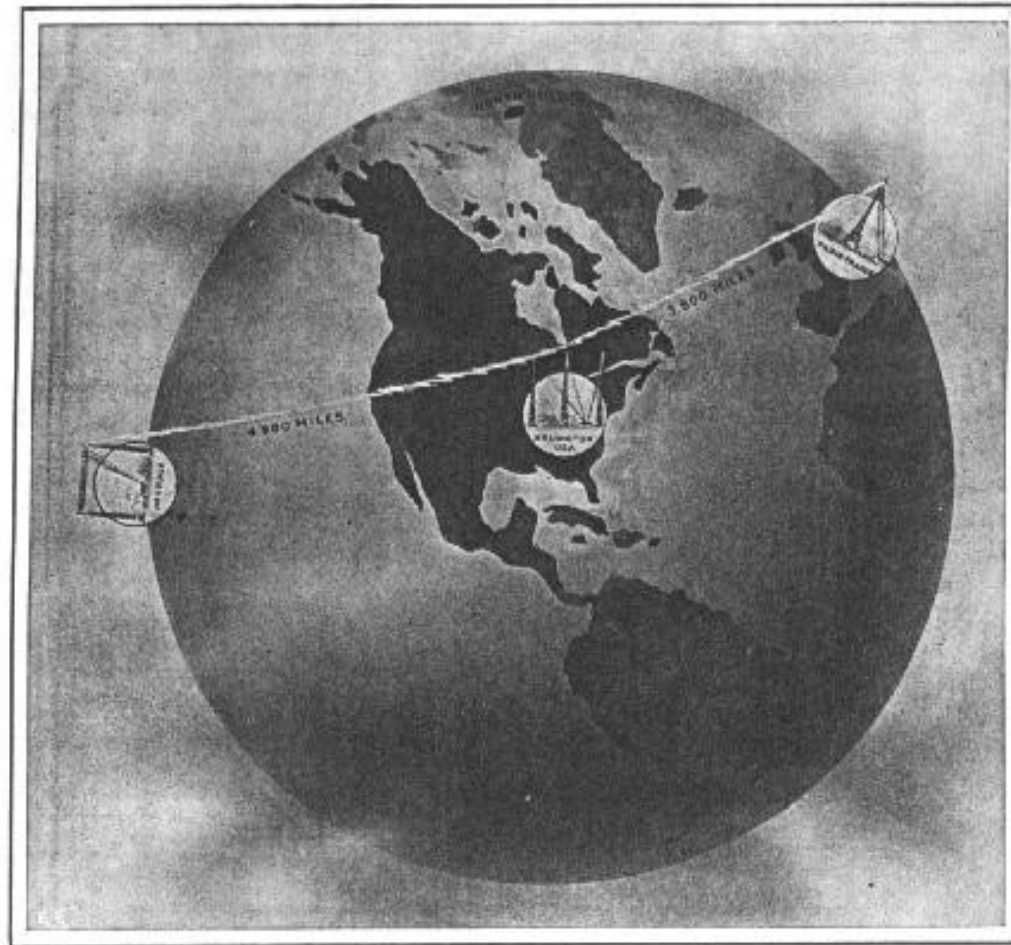
**February 1914 – E. H. Colpitts**  
devised a circuit for producing and  
modulating high-frequency oscillations.  
( *History of Engineering and Science in  
the Bell System* – p364)

**Vacuum-tube development continues.**



# By Wireless 'Phone from Arlington to Paris

*The Electrical Experimenter*, December, 1915, page 393:



**Graphic Illustration of Arlington to Honolulu and Arlington-Paris Radiophone Tests Recently Conducted; the Distances Covered Being 4,900 and 3,800 Miles Respectively.**



# AT&T AM Transmitter at Arlington

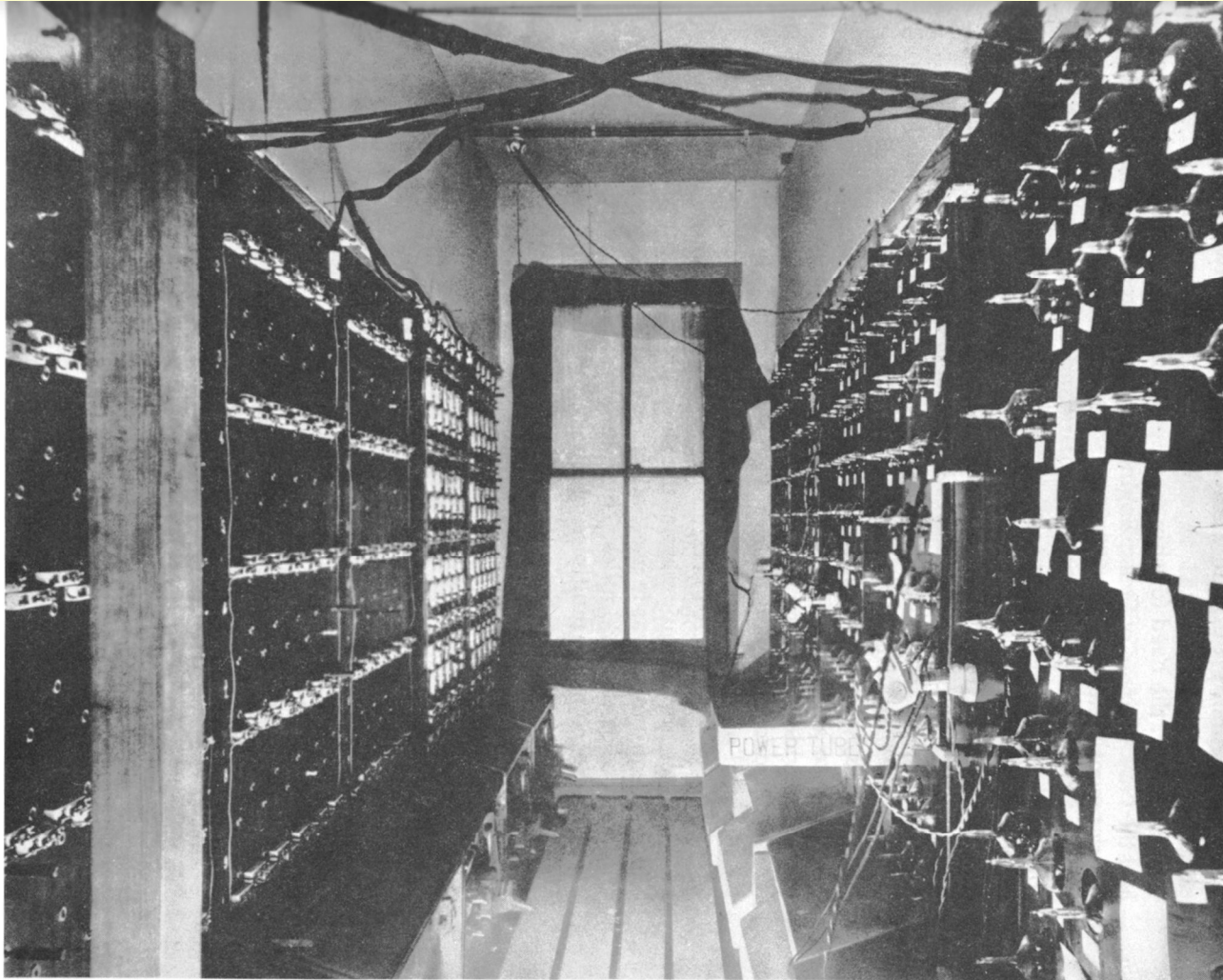


Fig. 5-7. Arlington long-wave transmitter of 1915. At right are some of the 550 tubes used in the final stage.

Fig.  
lou

**Linear amplifier using 550 Type-W tubes delivering 3KW AM carrier.**



# *The Wireless Age, April, 1915*



- .....the **Marconi Wireless Telegraph Company** will be ready to announce the commercial wireless telephone, long predicted and confidently awaited.
- The short distance Marconi wireless telephone now being developed for commercial use has a guaranteed working range of 50 kilometres (about 31 miles) between ships at sea carrying aerials 100 feet high and 200 feet span. This working range has been considerably exceeded in tests, during which it was also determined that the telephone can be set up, all connections made and the whole arrangement be put in working order in a half hour.

# Navy Voice RT ca. 1918



The sub-chaser set

# The State of the Electronic Art

## 1920

- Radio-Telegraphy
  - CW is the preferred method.
  - Regenerative receivers universally used.
- Long-Distance Wire-Line Telephony
  - Becomes viable after 1915
  - Vacuum tube repeaters
- Radio-Telephony
  - First transatlantic voice transmission – US Navy 1915
  - Applications for ships and aircraft
  - Broadcasting industry begins late 1920

# The State of the Electronic Art

## 1920

- Greatly Improved Vacuum-Tube Technology
  - AT&T
  - General Electric
- Radio Corporation of America – Formed 1919
  - Marconi Wireless Telegraph Company of America (Navy)
  - General Electric Company
  - Westinghouse
  - United Fruit Company
  - Sarnoff appointed General Manager and late becomes President



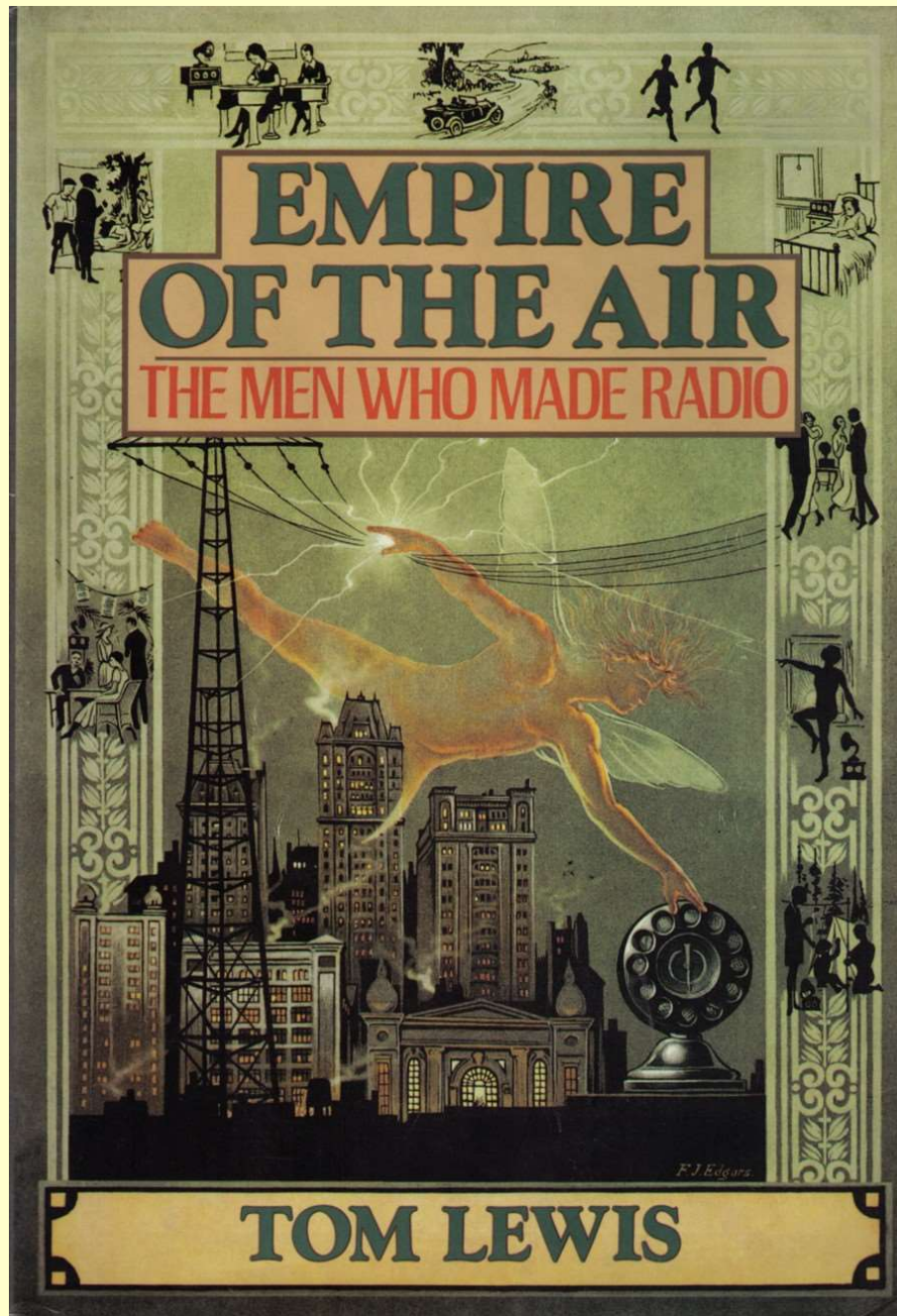
# Armstrong

- Major, U.S. Army Signal Corps – 1917-1919
- Becomes largest stockholder in RCA
  - Superheterodyne patent
  - Superregenerative patent
- Marries Sarnoff's secretary – Marion McInnis
- Continues working at Columbia for \$1 a year.
- Armstrong and Sarnoff observe the anniversary of Belmar for many years.
- Develops FM Broadcasting in the 1930's
- Commits suicide on the 40<sup>th</sup> anniversary of the Belmar demonstration.



ARMSTRONG FAMILY ARCHIVES





# A Good Read

Also:

- Video  
Ken Burns
- Radio Drama  
Dave Ossman  
(Fire-Sign Theater)