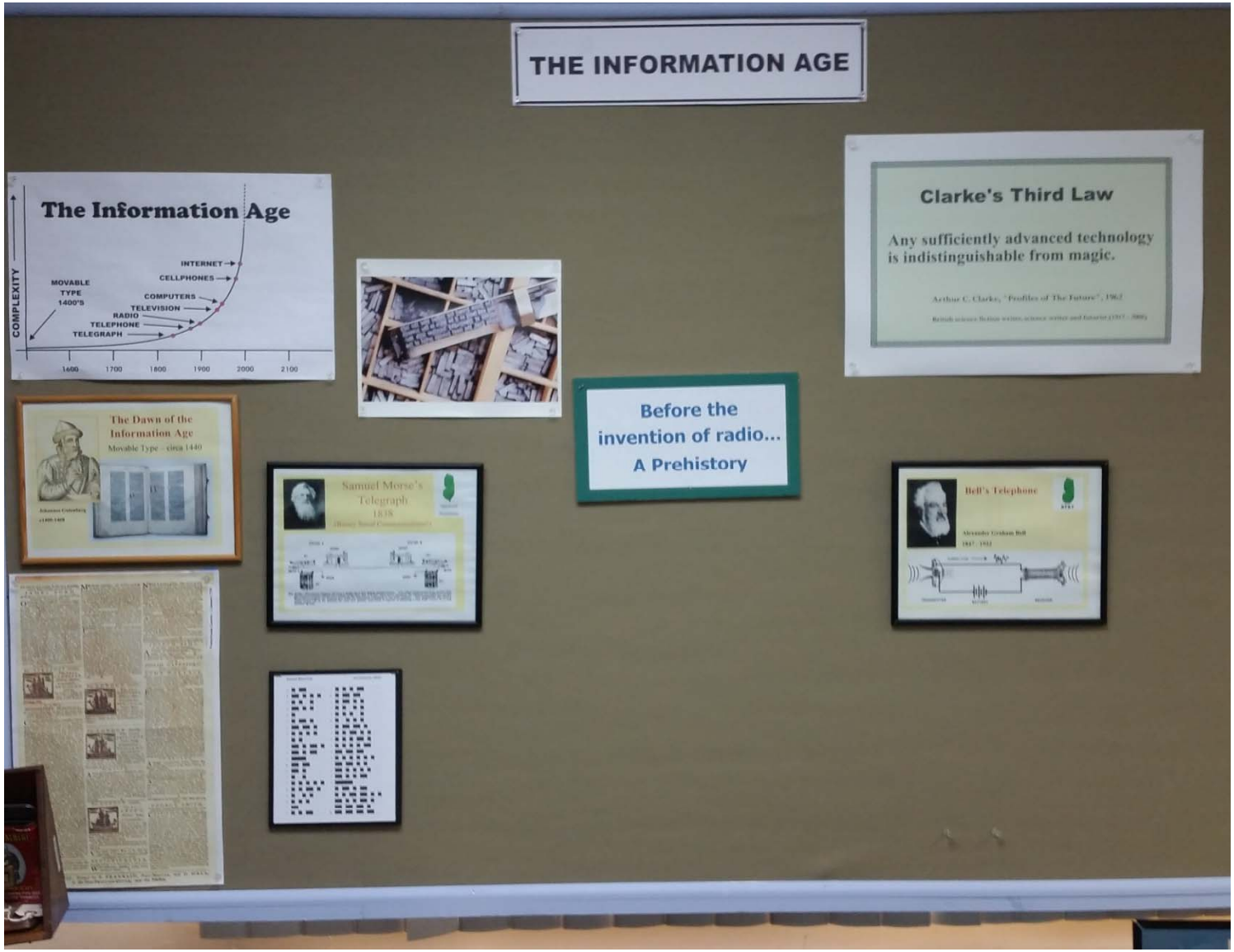
The Radio Technology Museum

New Displays

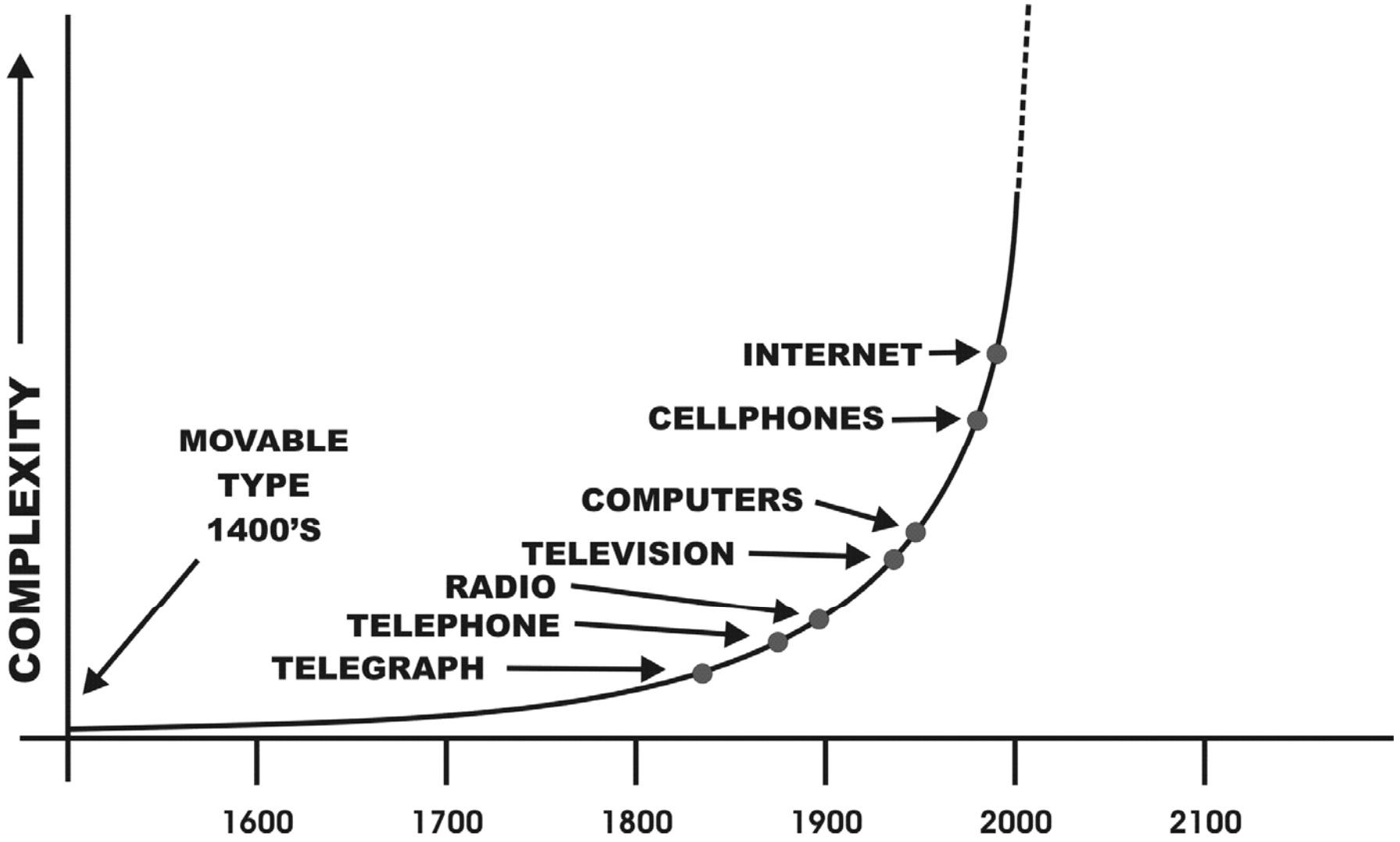
The Early Days

In the Beginning

In the Beginning



The Information Age



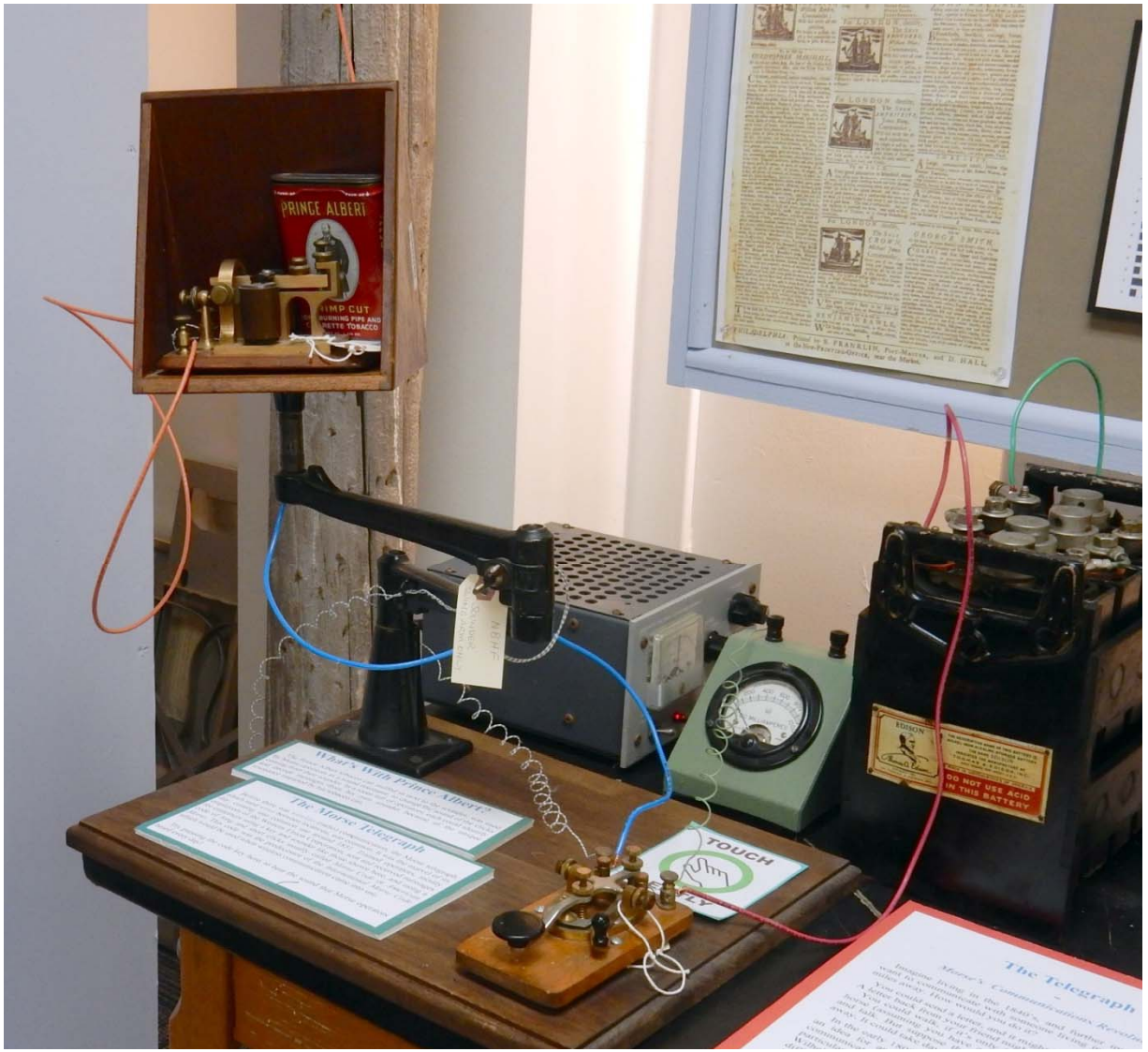
Clarke's Third Law

Any sufficiently advanced technology is indistinguishable from magic.

Arthur C. Clarke, "Profiles of The Future", 1962

British science fiction writer, science writer and futurist (1917 - 2008)

Morse Telegraph



Radio

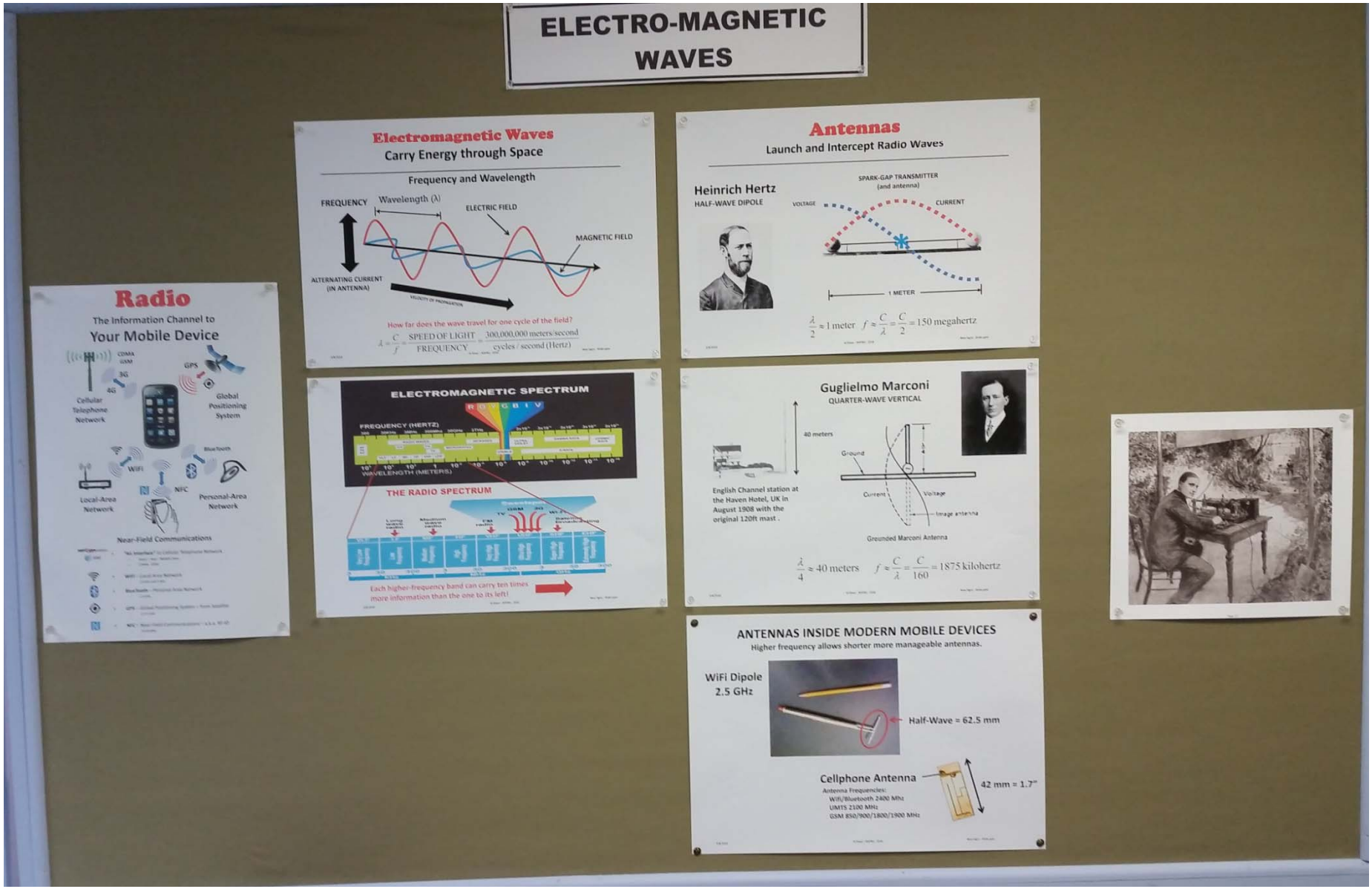
The Information Channel to

Your Mobile Device

verizon wireless
at&t

- **"Air Interface"** to Cellular Telephone Network
  - Voice – Text – Mobile Data
  - CDMA - GSM
- **WiFi** – Local Area Network
  - 2.4 GHz and 5 HGz
- **BlueTooth** – Personal Area Network
  - 2.4 GHz
- **GPS** – Global Positioning System – from Satellite
  - 1.575 GHZ
- **NFC** – Near-Field Communications – a.k.a. RF-ID
  - 13.56 MHz

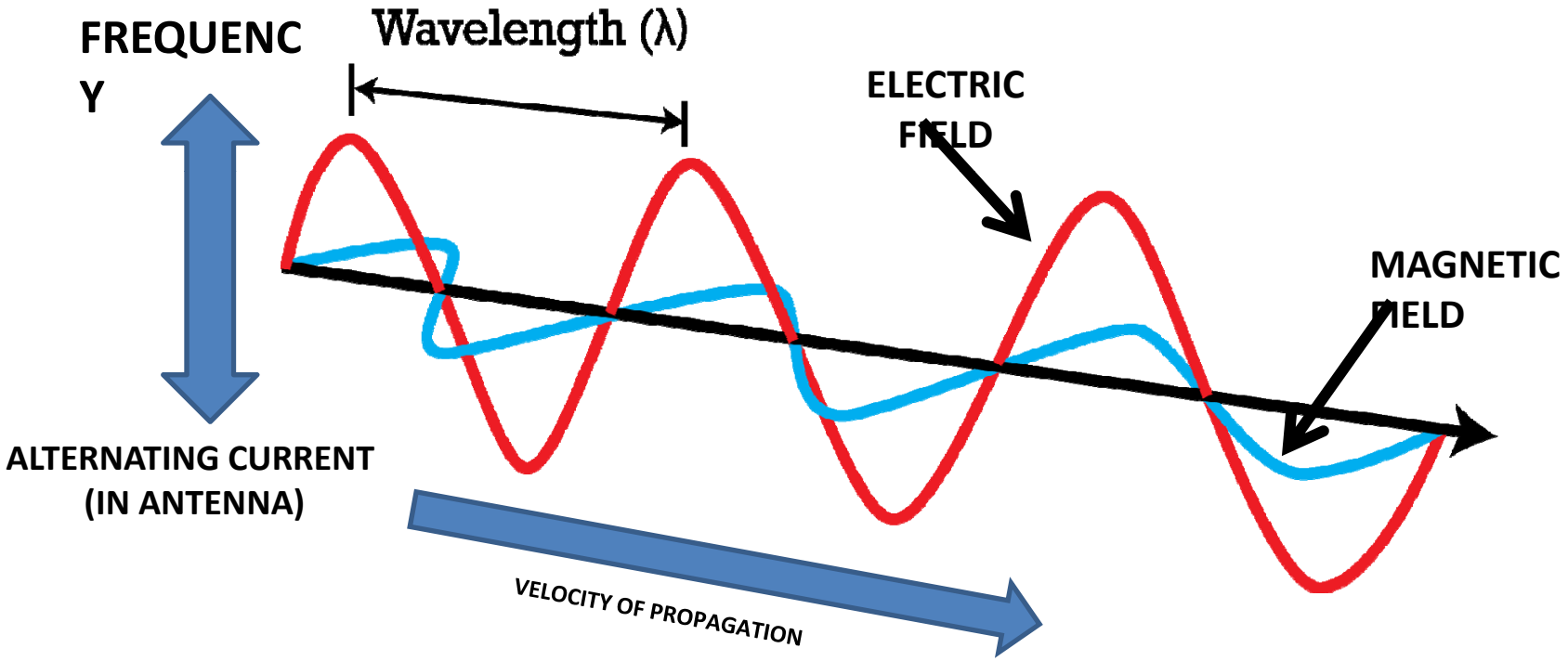
Electro-Magnetic Waves



Electromagnetic Waves

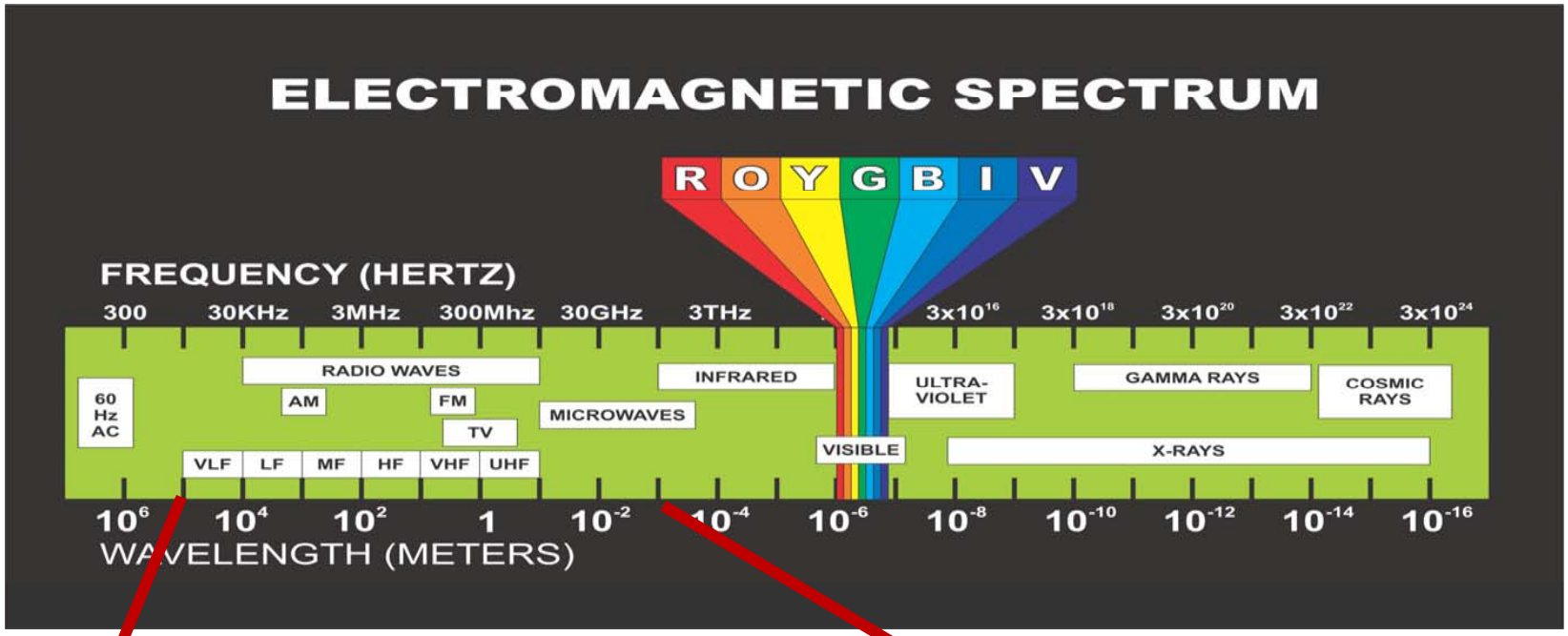
Carry Energy through Space

Frequency and Wavelength

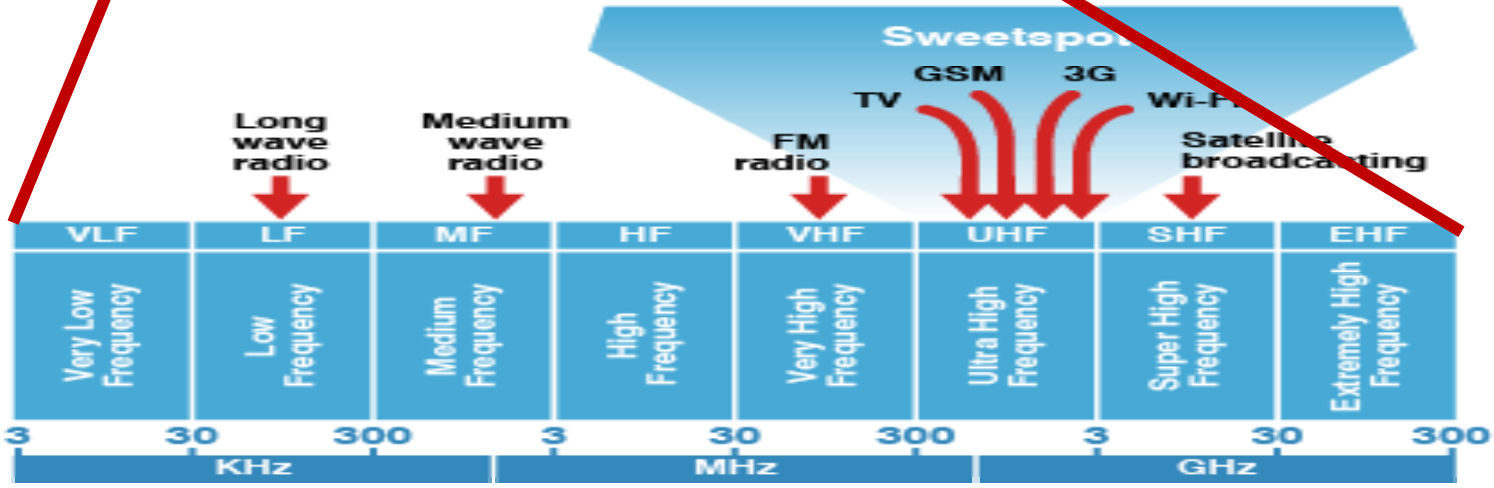


How far does the wave travel for one cycle of the field?

$$\lambda = \frac{C}{f} = \frac{\text{SPEED OF LIGHT}}{\text{FREQUENCY}} = \frac{300{,}000{,}000 \text{ meters/second}}{\text{cycles/second (Hertz)}}$$



THE RADIO SPECTRUM



Each higher-frequency band can carry ten times more information than the one to its left!

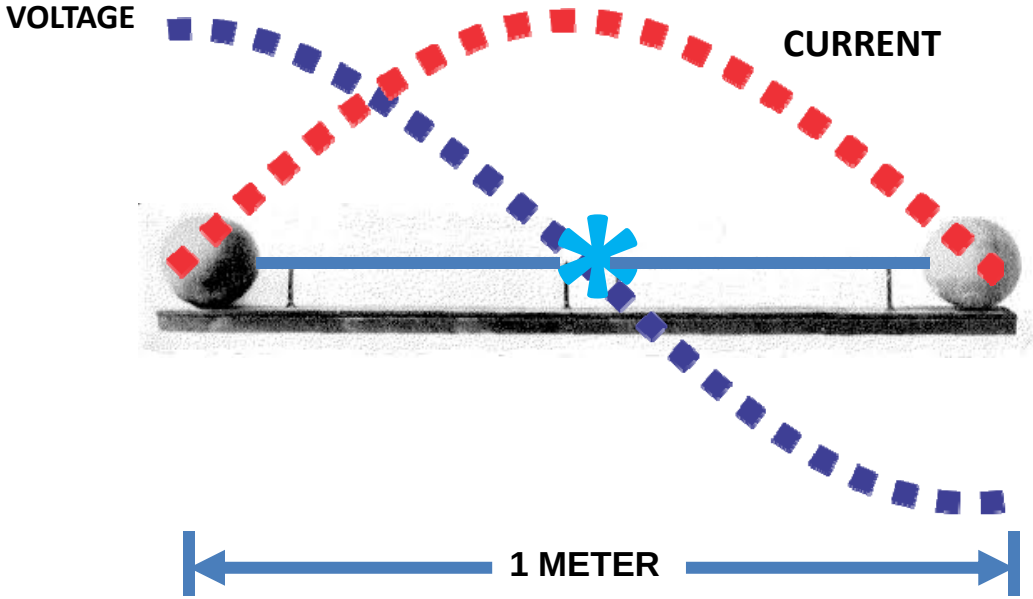
Antennas

Launch and Intercept Radio Waves

Heinrich Hertz

HALF-WAVE DIPOLE

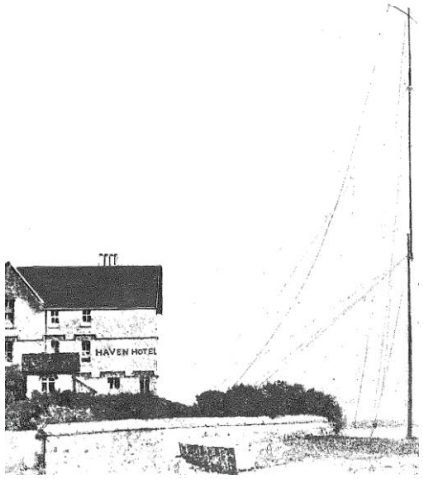
SPARK-GAP TRANSMITTER
(and antenna)



$$\frac{\lambda}{2} \approx 1\,\text{meter} \quad f \approx \frac{C}{\lambda} = \frac{C}{2} = 150\,\text{megahertz}$$

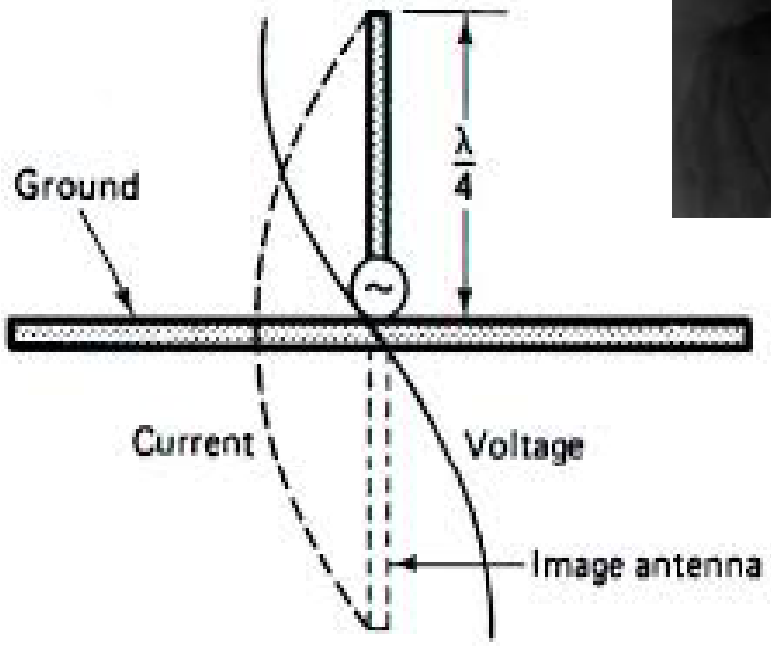
Guglielmo Marconi

QUARTER-WAVE VERTICAL



40 meters

English Channel station at the Haven Hotel, UK in August 1908 with the original 120ft mast .



Grounded Marconi Antenna

$$\frac{\lambda}{4} \approx 40\,\text{meters} \qquad f \approx \frac{C}{\lambda} = \frac{C}{160} = 1875\text{kilohertz}$$

ANTENNAS INSIDE MODERN MOBILE DEVICES

Higher frequency allows shorter more manageable antennas.

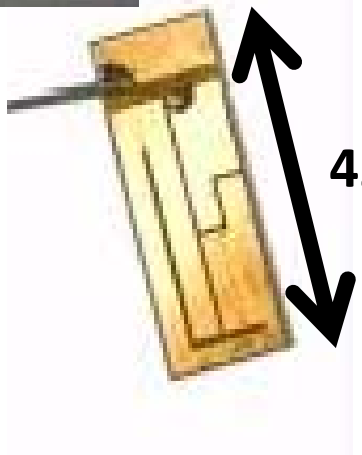
WiFi Dipole 2.5 GHz

Half-Wave = 62.5 mm

Cellphone Antenna

Antenna Frequencies:

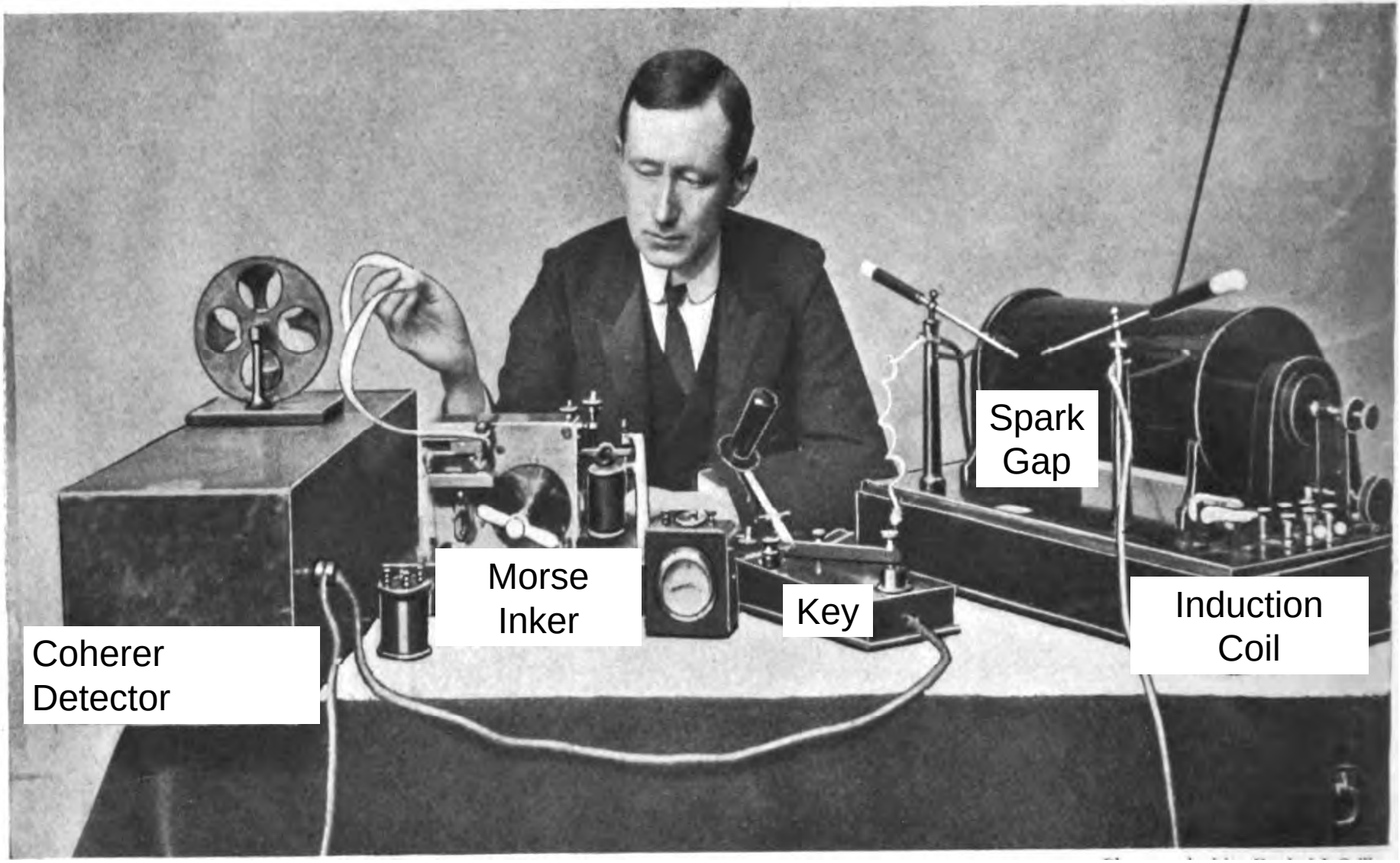
- **Wifi/Bluetooth 2400 Mhz**
- **UMTS 2100 MHz**
- **GSM 850/900/1800/1900 MHz**



42 mm = 1.7”

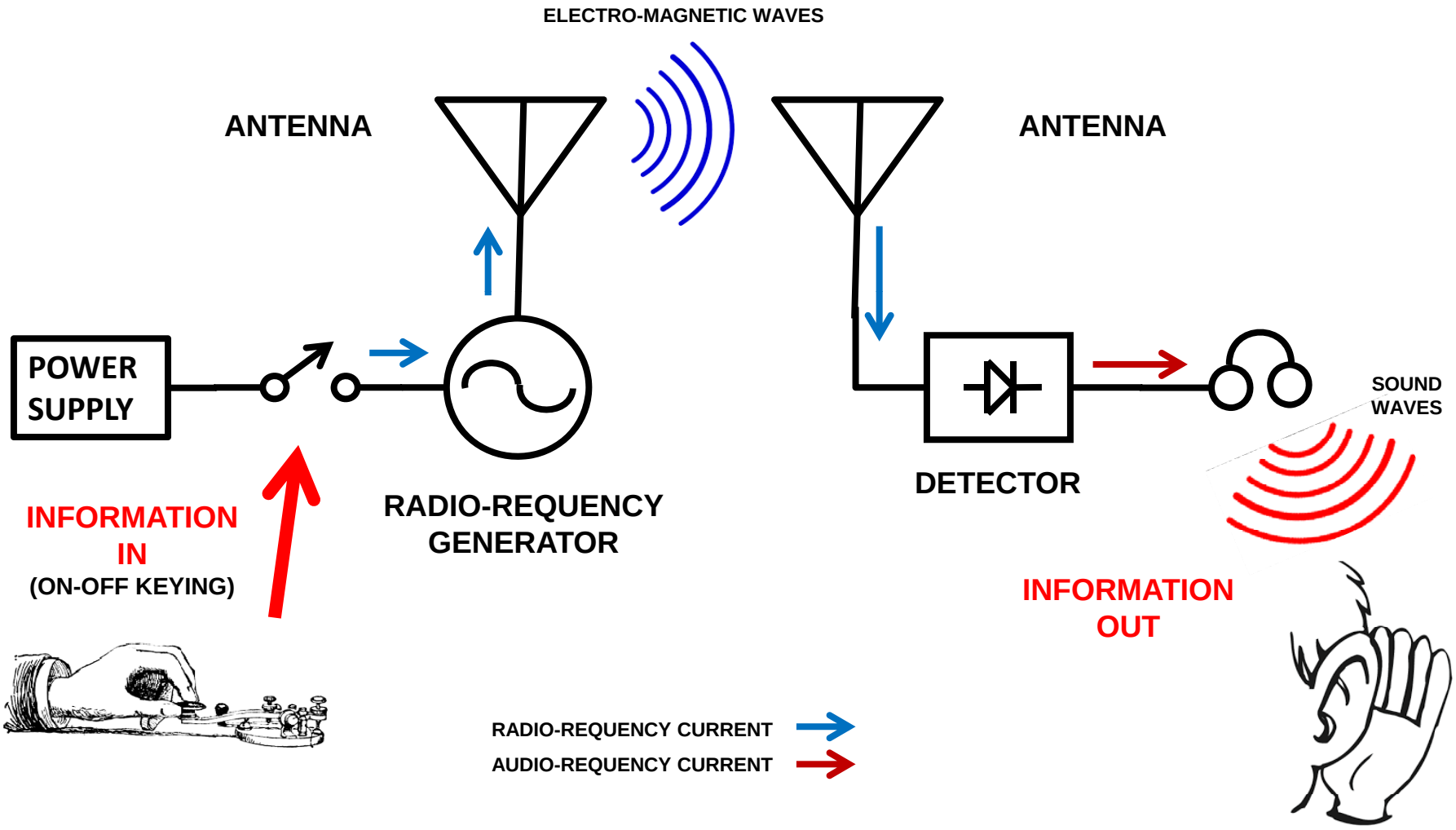
Wireless Telegraphy

Wireless Station ca. 1900



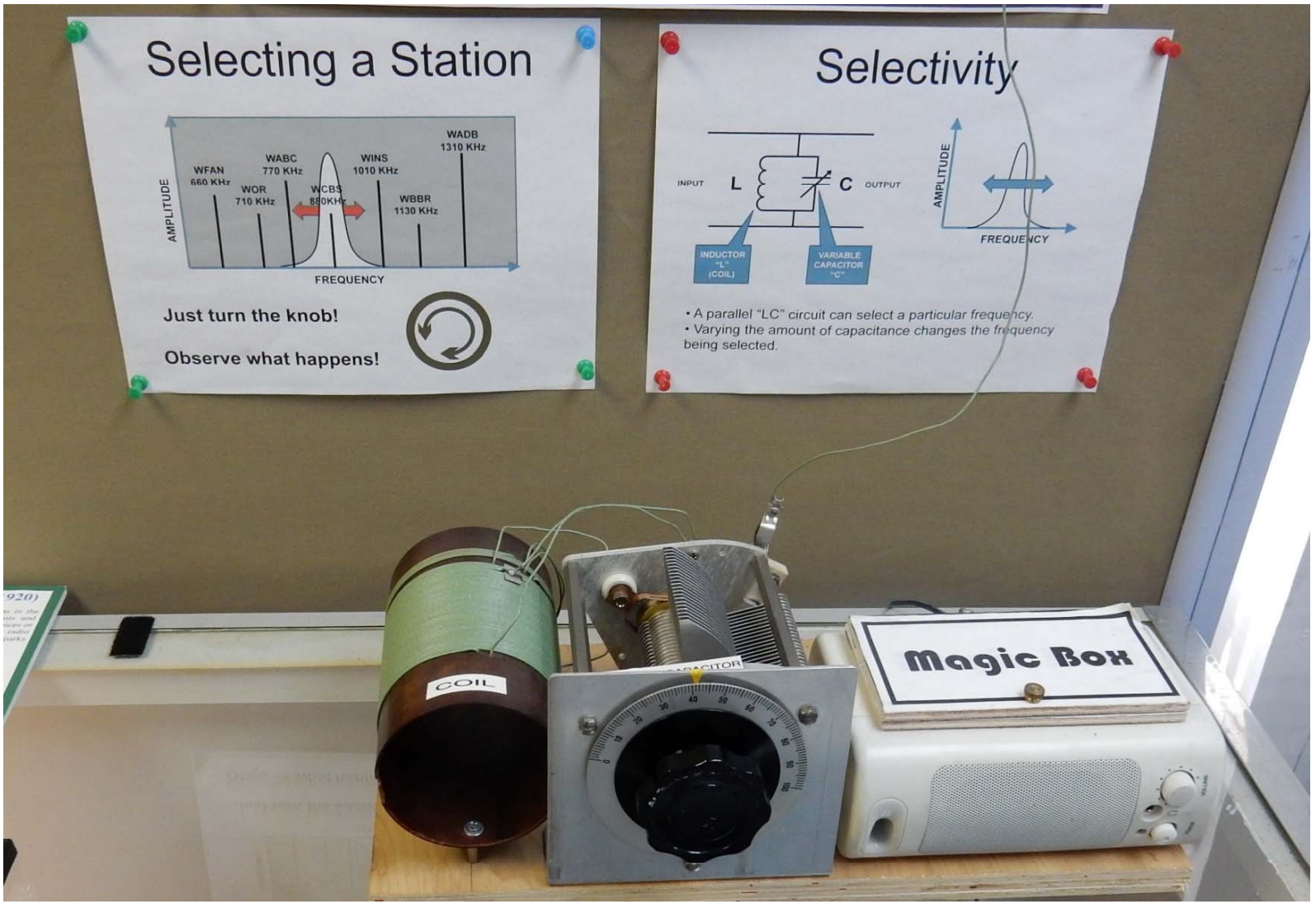
Guglielmo Marconi at the key.

A SIMPLE RADIO SYSTEM



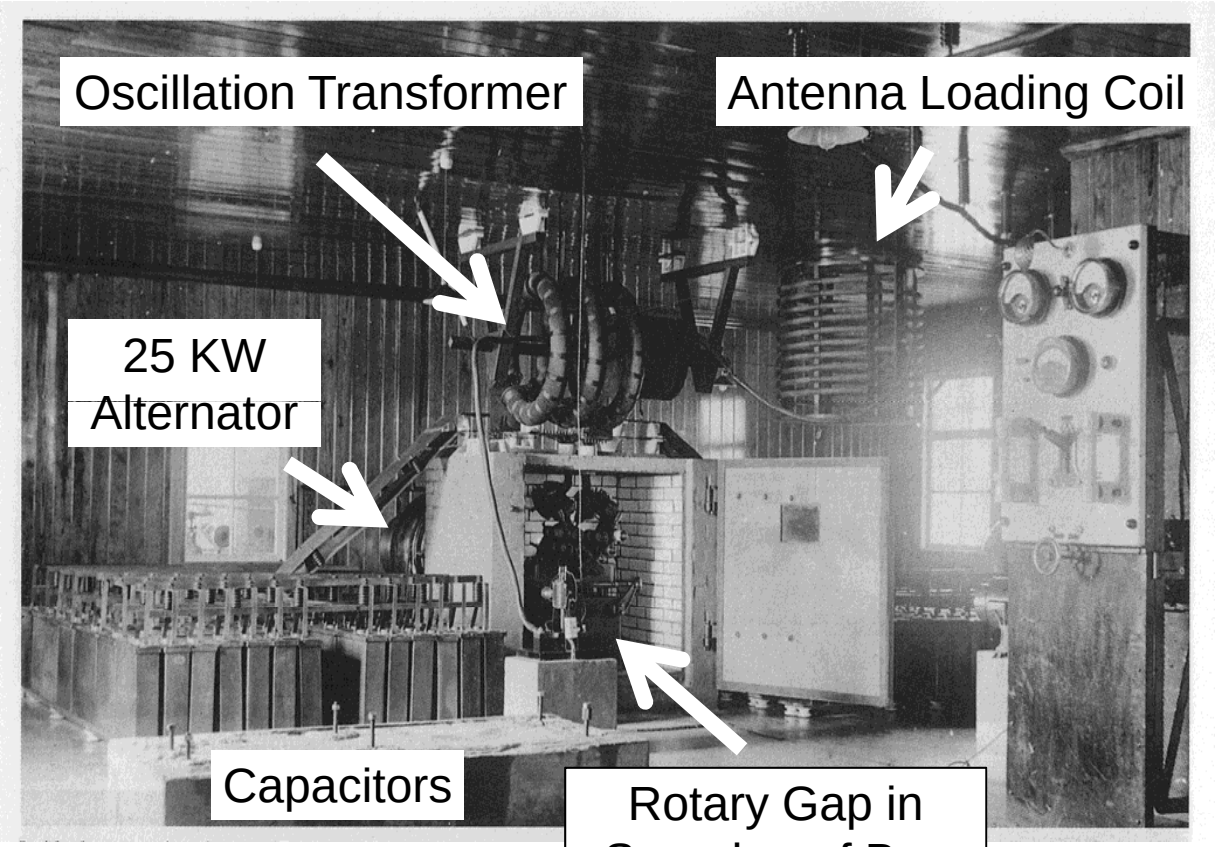
Spark Transmitter

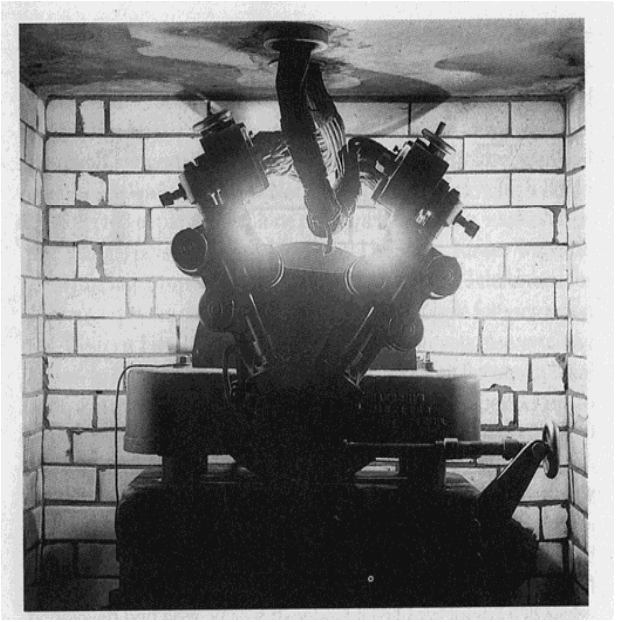
Simple Receiver



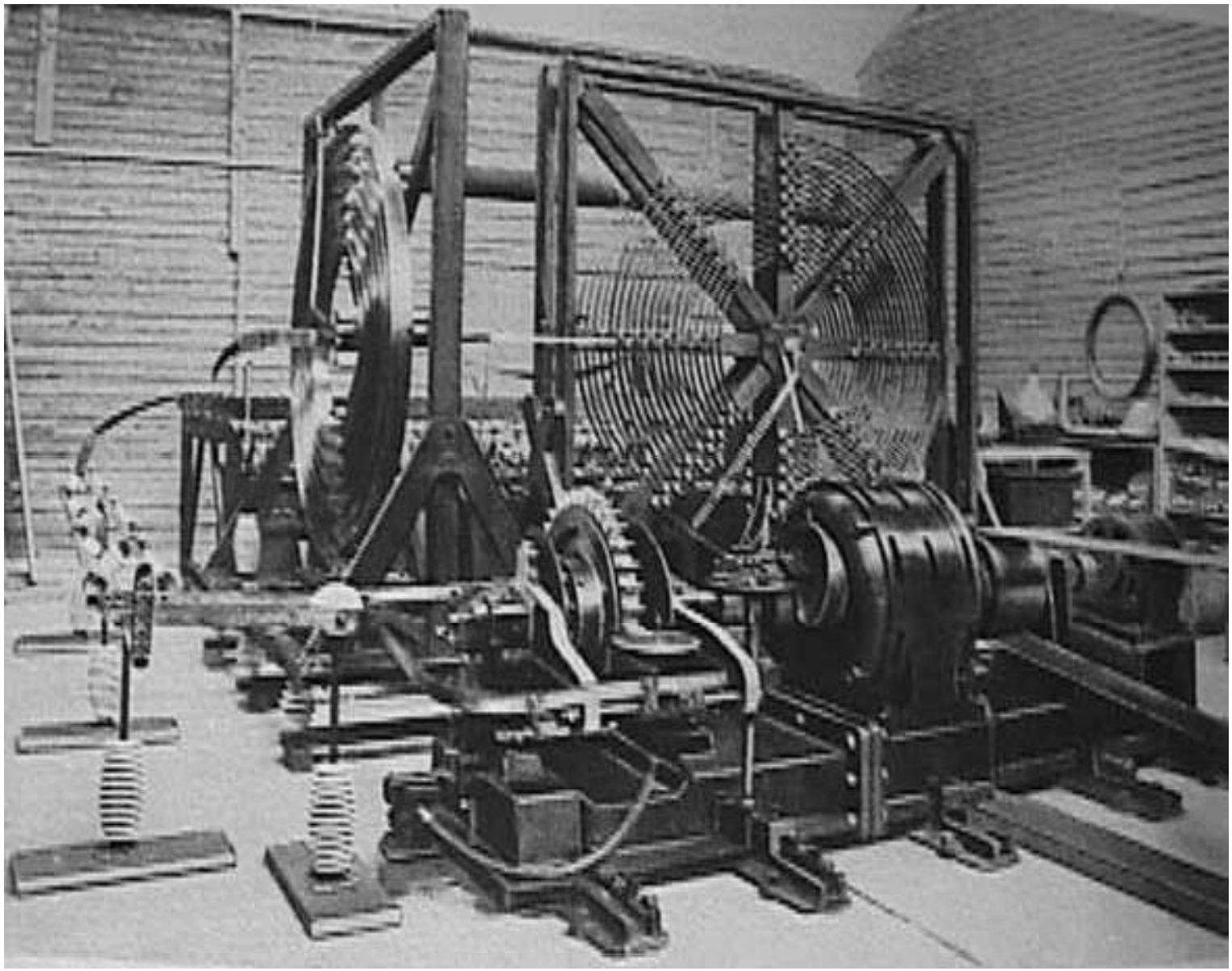
RF amplification and AVC in "Magic Box" make this work well for the inexperienced operator.

Marconi Transmitter, Poldhu, Wales - ca. 1906



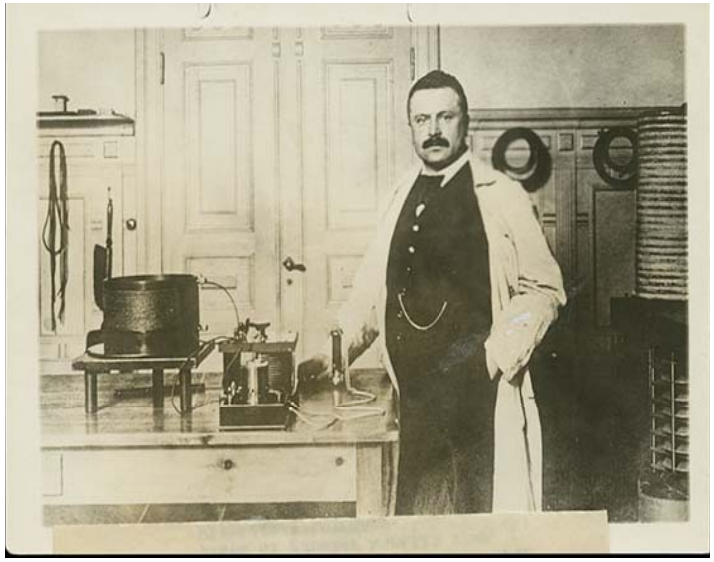


Rotary Gap
In Action

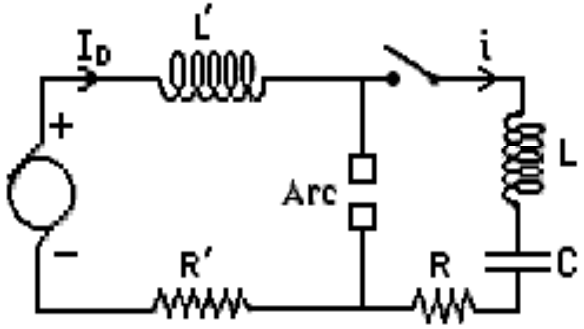


50 KW Synchronous-Gap Spark Transmitter
Societe Francaise Radioelectrique

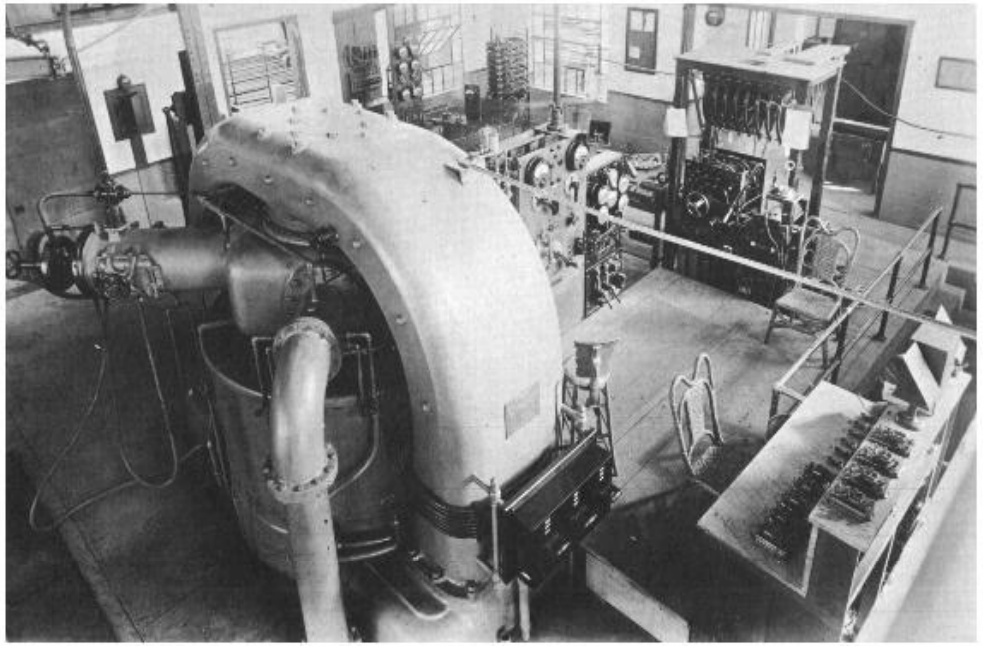
Poulsen Arc Continuous-Wave Transmitter



Vladimir Poulsen with small arc converter.

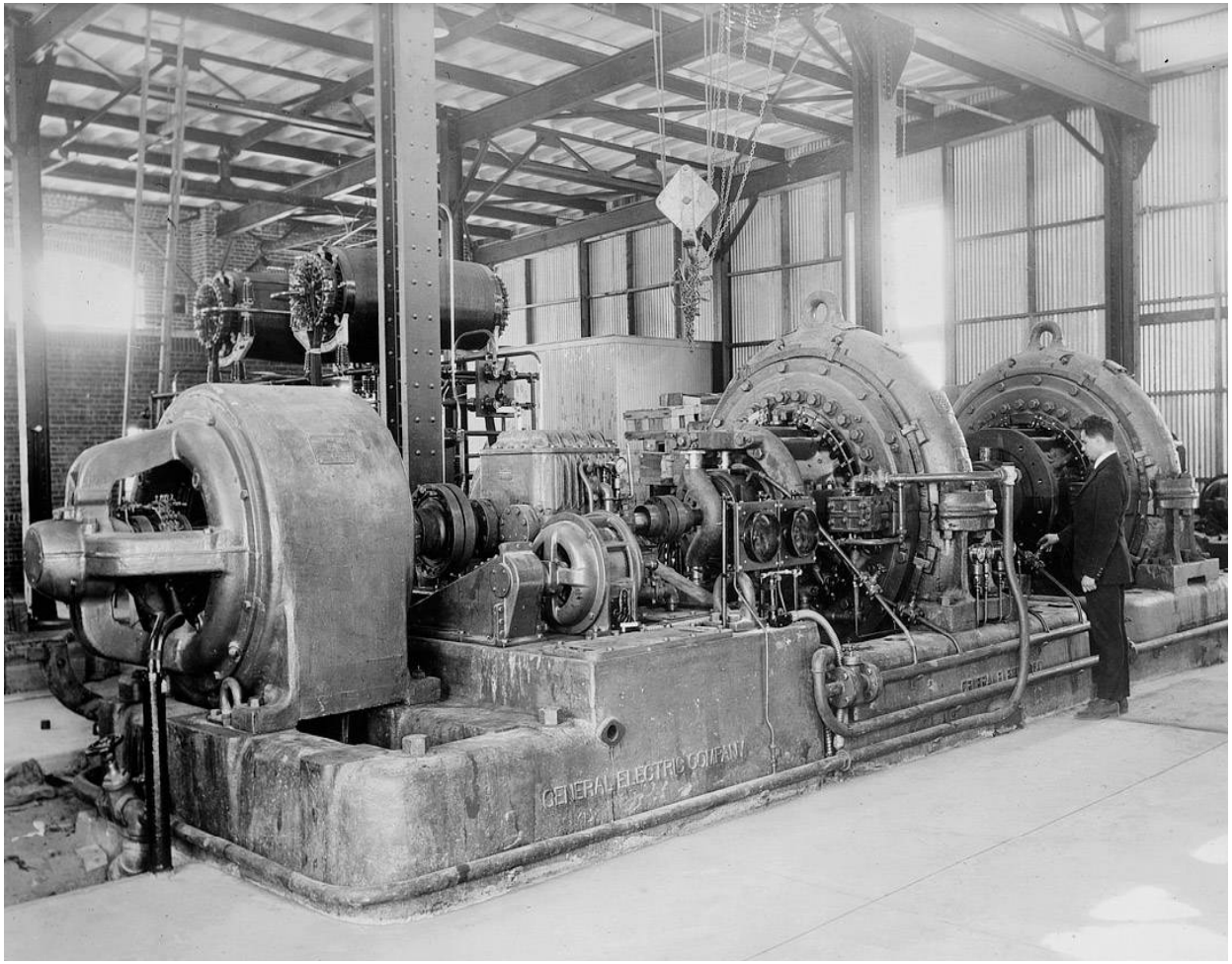


The DC arc has negative resistance causing the LC circuit to oscillate.



**350 KW Federal Telegraph Co.
Arc Transmitter - 1919**

Alexanderson Alternator Continuous-Wave Transmitter



AC Motor (left) turns high-frequency alternator (center) producing 200 KW in the frequency range of 15 – 30 KHz.

Early Semiconductors

Early Vacuum Tubes

ELECTRON DEVICES

VACUUM TUBES - TRANSISTORS - INTEGRATED CIRCUITS

VACUUM TUBES

AMPLIFICATION: MAKING THE QUIET LOUD.

DeForest “Audion”
1906

201A
1922

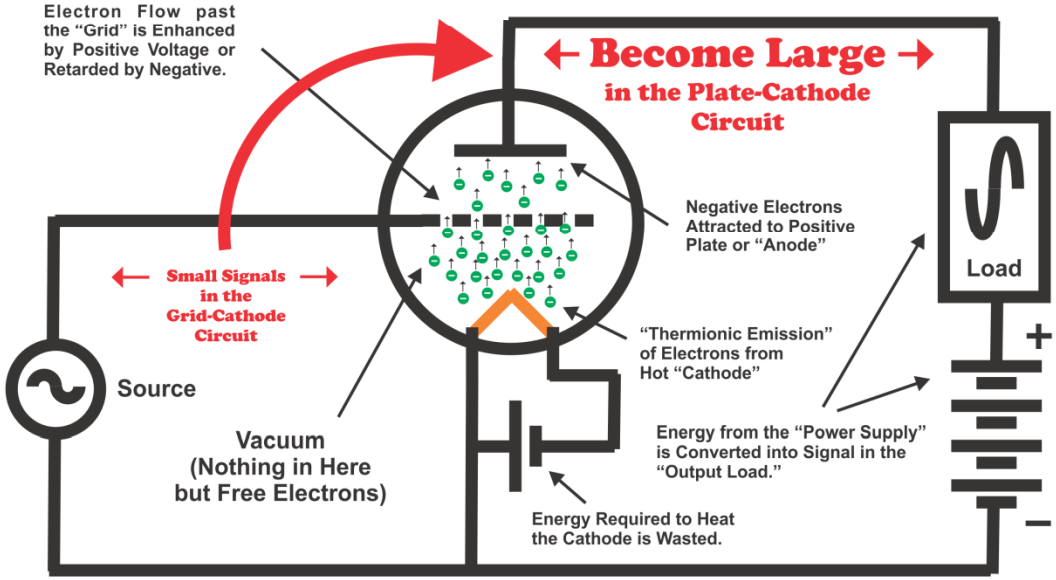
1932

Metal Tubes
1935

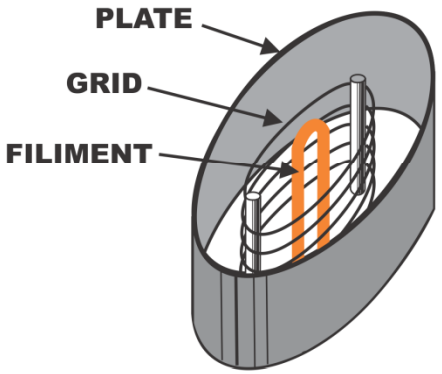
Miniature
Tubes
1939

Subminiature
Tubes
1942

Nuvistors
1959



SCHEMATIC REPRESENTATION



TRIODE VACUUM TUBE INTERNAL CONSTRUCTION

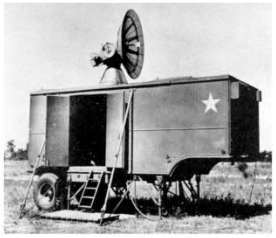
RADIO

Atwater Kent 82Q
7 Tubes

TELEVISION

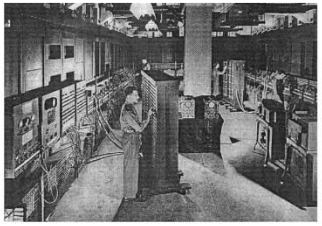
Philco Predicta
25 Tubes

RADAR



SCR-584
100 Tubes

COMPUTERS



ENIAC
18,000 Tubes

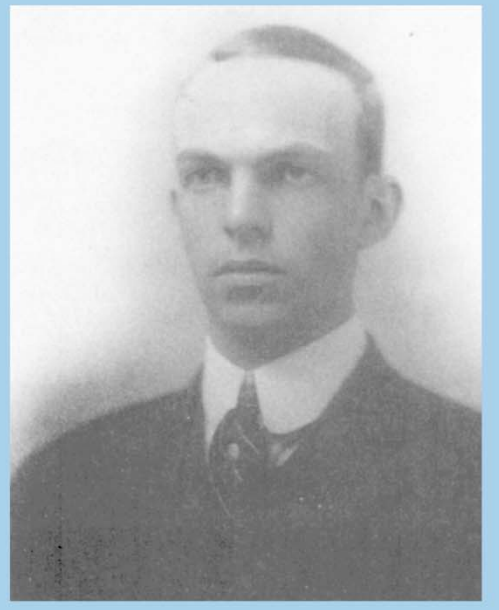
Armstrong and the Dawn of the Electronic Age

REGENERATION

Edwin H. Armstrong - 22 September 1912

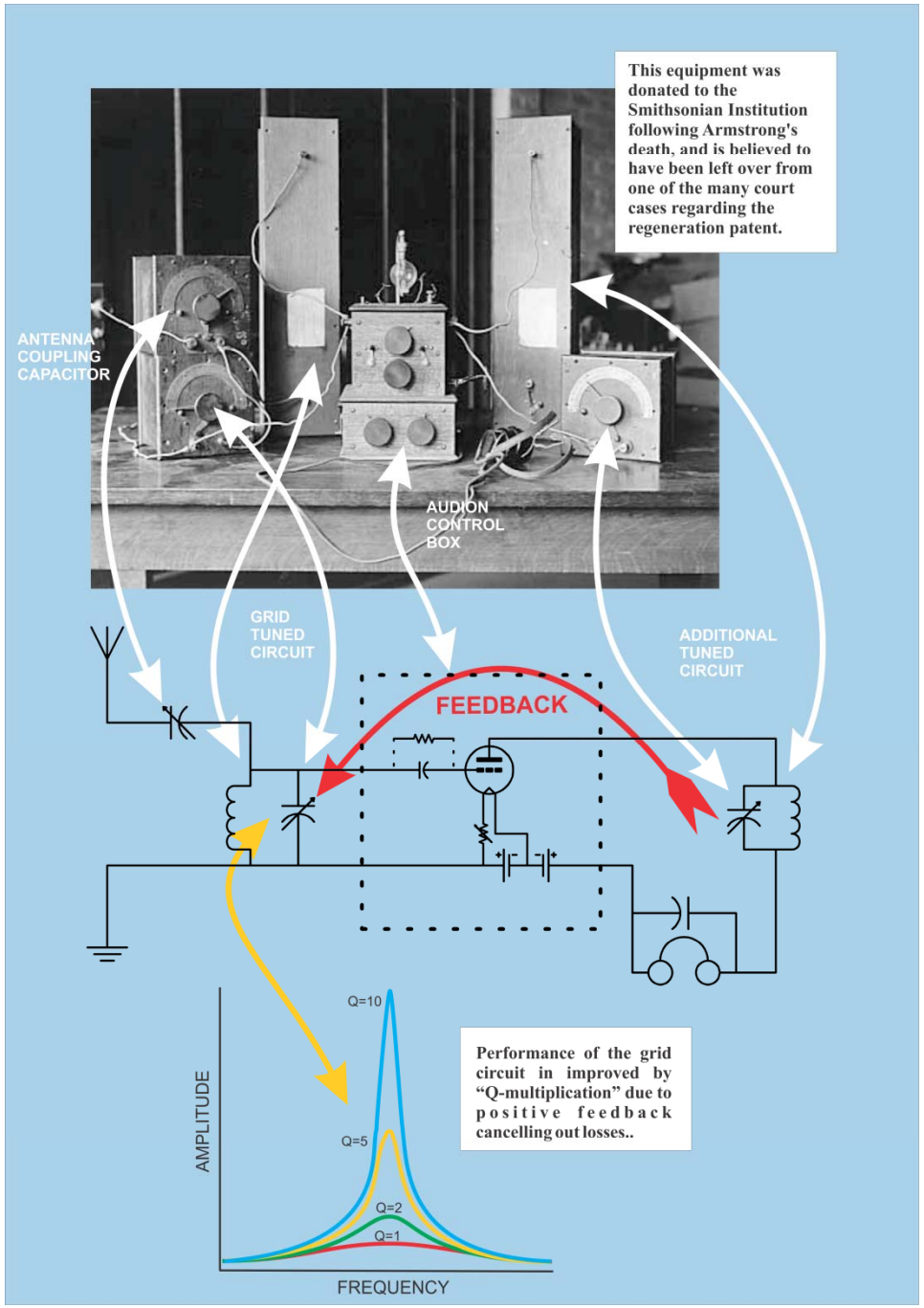
"Great amplification obtained at once!"

- **Sensitivity increased 100-fold.**
- **Improved selectivity**
- **Receive continuous-wave signals**
  CW more efficient than spark
- **First vacuum-tube RF oscillator**
  The enabling technology for both CW radio-telegraphy and radio-telephony.



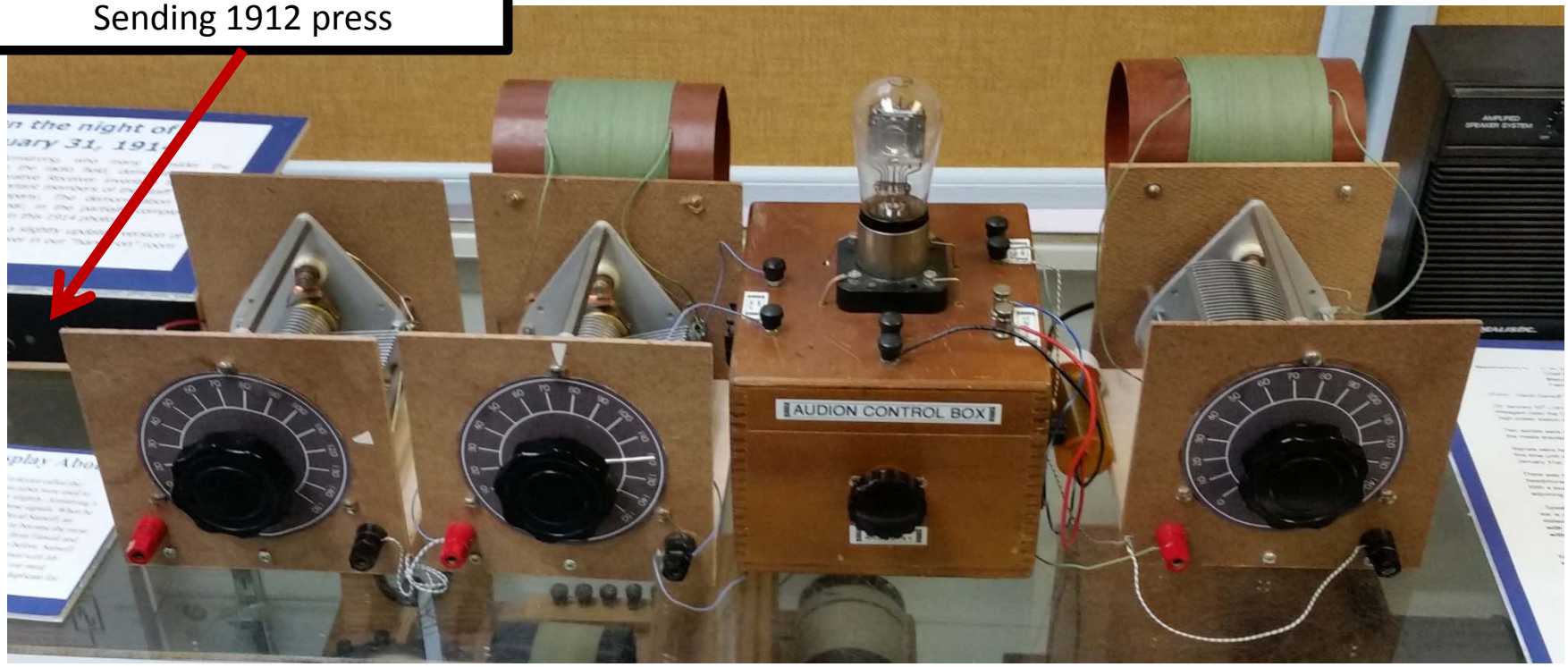
Armstrong while at Columbia

Armstrong Family Archive


This equipment was donated to the Smithsonian Institution following Armstrong's death, and is believed to have been left over from one of the many court cases regarding the regeneration patent.
ANTENNA COUPLING CAPACITOR
AUDION CONTROL BOX
GRID TUNED CIRCUIT
ADDITIONAL TUNED CIRCUIT
FEEDBACK
Q=10
Q=5
Q=2
Q=1
AMPLITUDE
FREQUENCY
Performance of the grid circuit in improved by "Q-multiplication" due to positive feedback cancelling out losses..

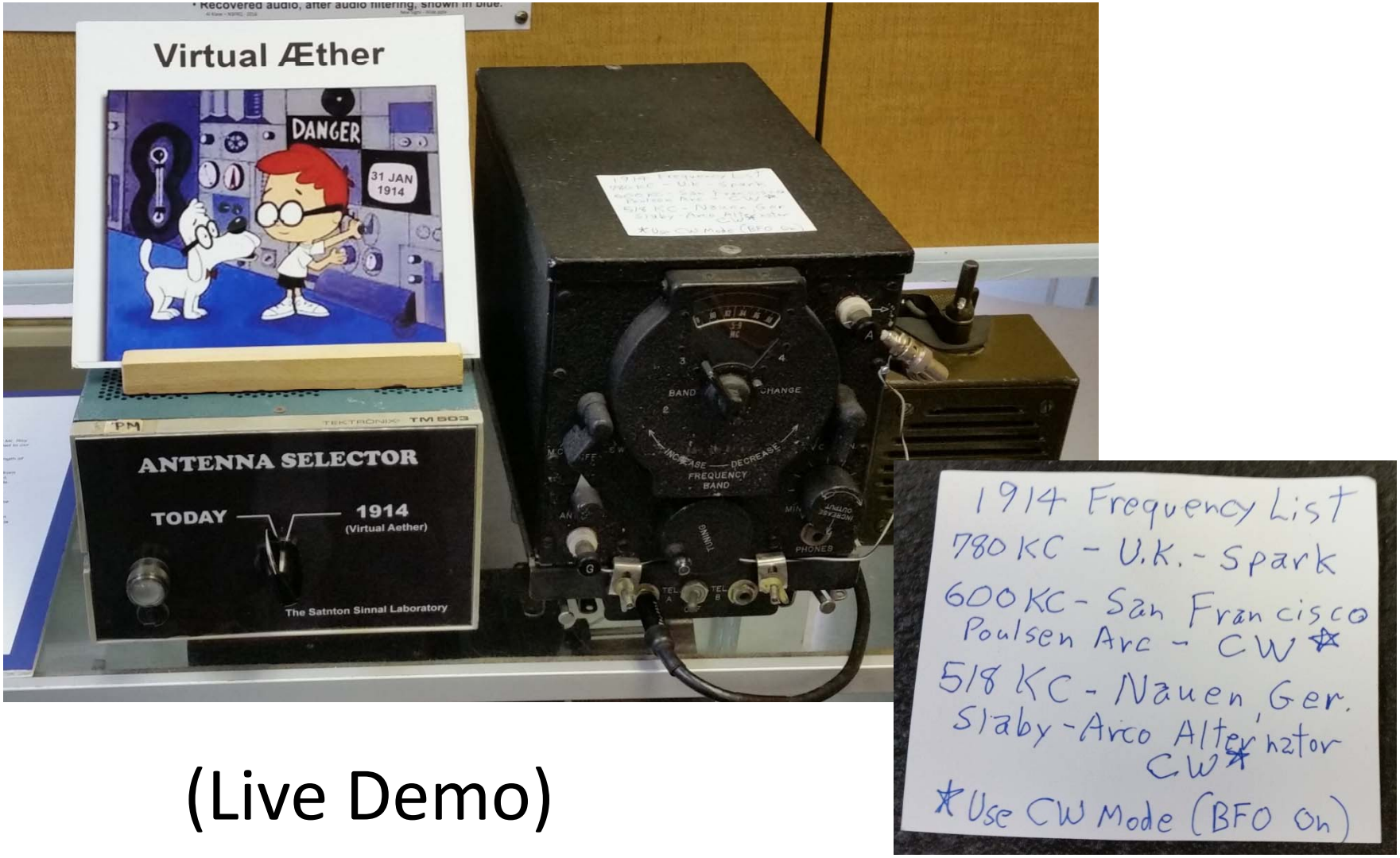
Discovery of Regemeration (Live Demo)

MCC
(Marconi Cape Cod)
Simulated Spark Transmitter
Sending 1912 press



Virtual Ether

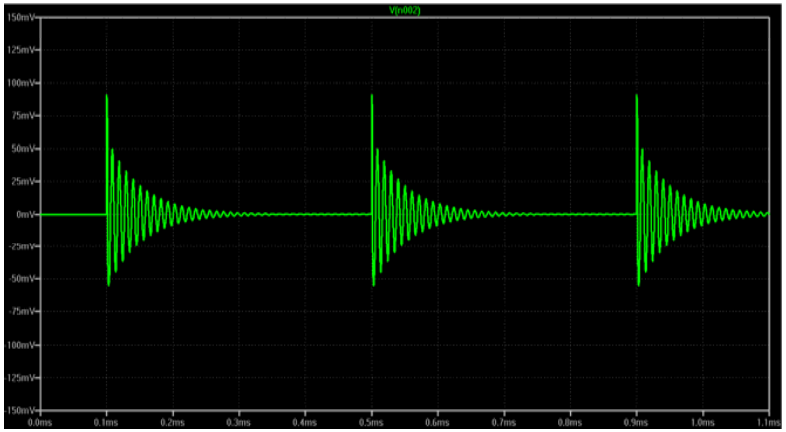
Stations Heard by Armstrong and Sarnoff at Belmar 31 Jan 1914

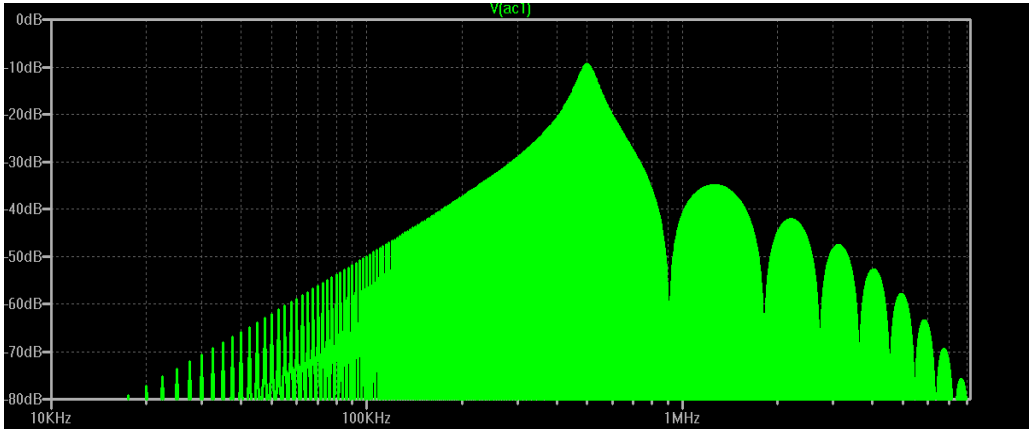


(Live Demo)

Damped Waves:

- Produced by spark-gap transmitters.
- Each spark discharge causes the RF tuned circuit to ring like a bell or plucked string.
- Each pulse dies away.
- The carrier wave is inherently amplitude-modulated at the spark frequency.
- At the receiver, detection in easily accomplished with a simple rectifier.





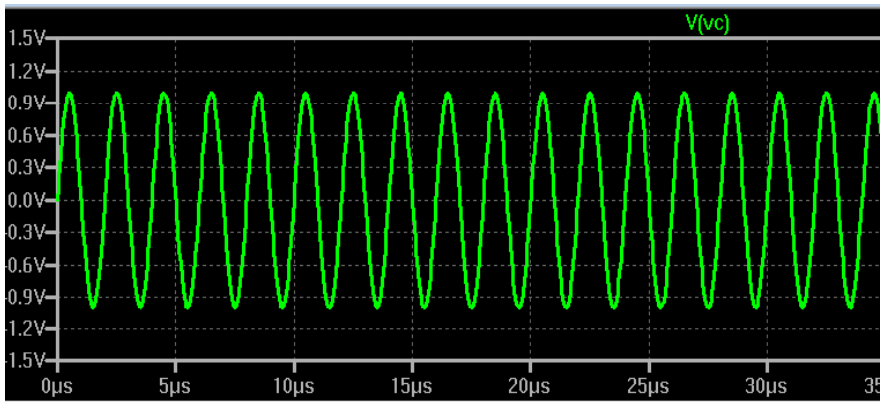
10 KHz 100 KHz 500 KHz 1 MHz 10 MHz

Time Domain ->

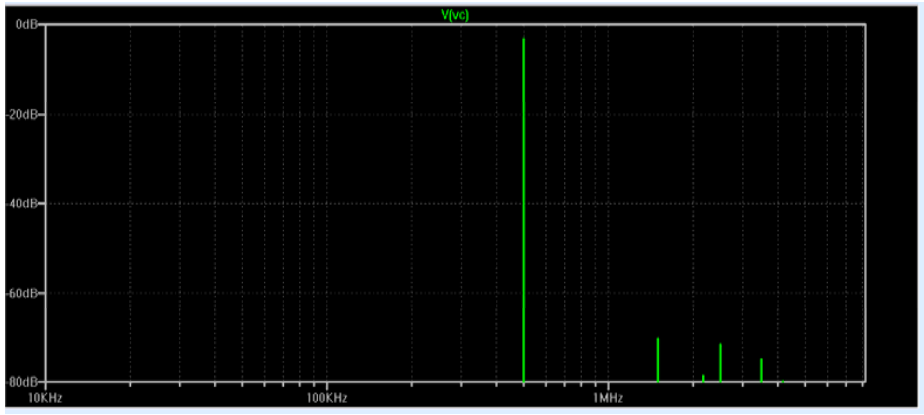
Frequency Domain ->
Very wide bandwidth

Continuous Waves:

- Greater efficiency due to narrow bandwidth.
- Produced by:
  - High-Frequency rotating machinery, e.g.the Alexanderson Alternator
  - Poulsen Arc Converter
  - Vacuum-Tube or Solid-State Oscillators



Time Domain ->

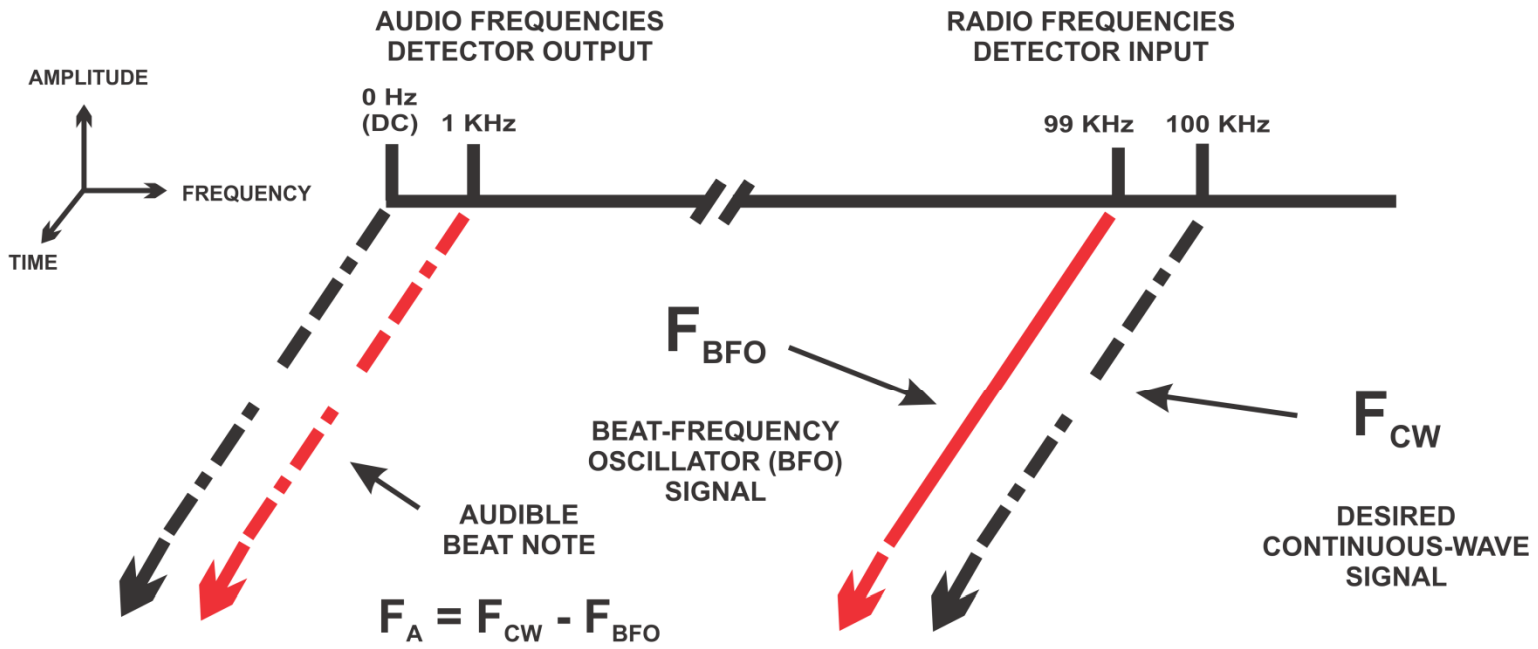


Frequency Domain ->

Receiving Continuous Waves

HETERODYNE DETECTION

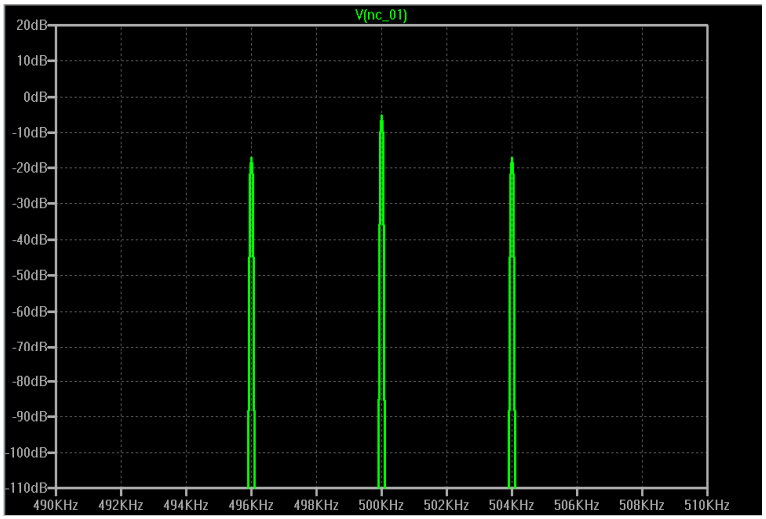
The Old Frequency-Changer Trick!



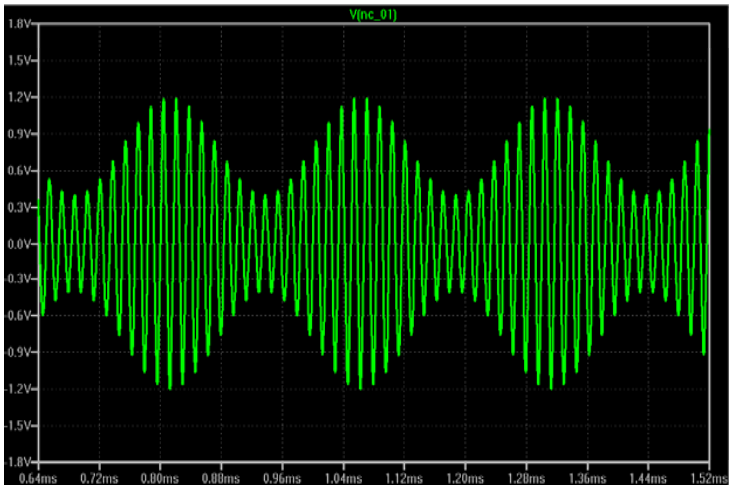
This is easy with an Armstrong regenerative detector in the "autodyne" (oscillating) mode.

Amplitude Modulation:

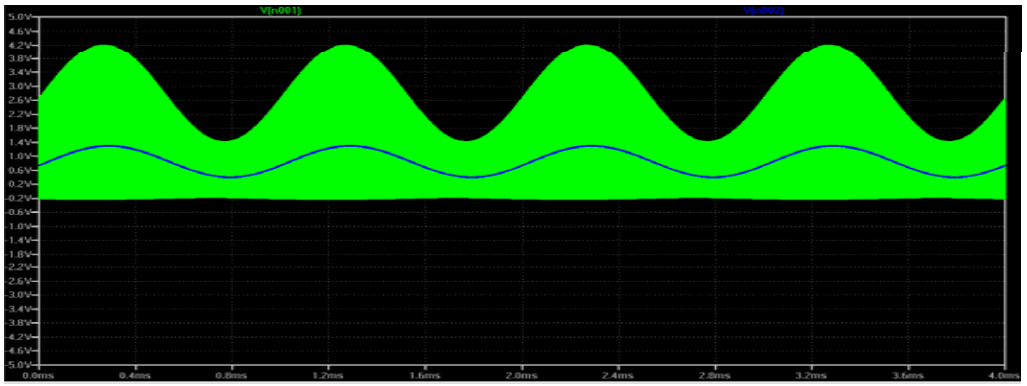
- Produced by modulating a continuous-wave (CW) source:
  - High-Frequency rotating machinery, e.g. the Alexanderson Alternator
  - Poulsen Arc Converter
  - Vacuum-Tube or Solid-State Oscillators



Frequency Domain ->
500KHz modulated by 4KHz



Time Domain ->
60KHz modulated by 4KHz



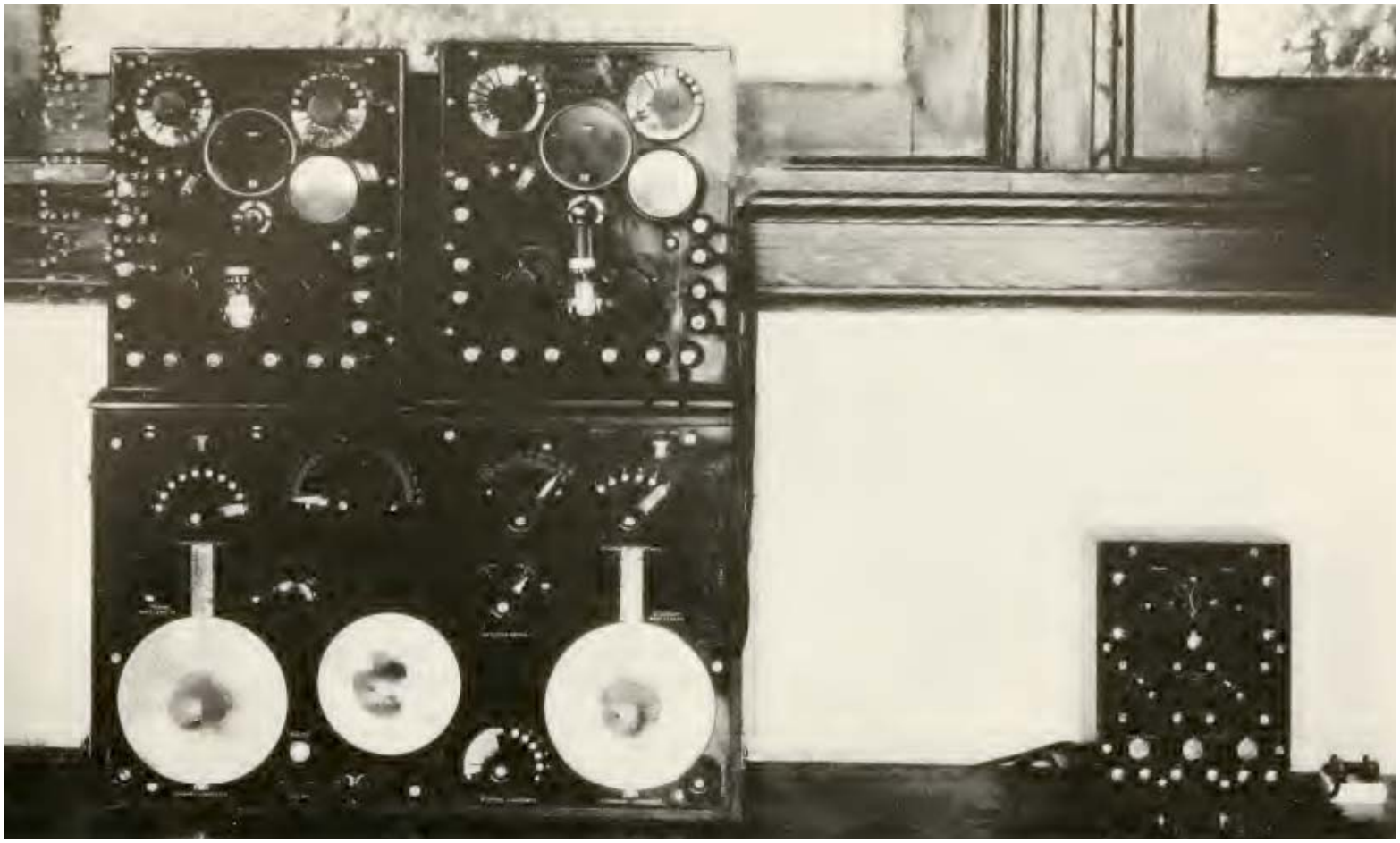
Detection:

- **Bottom half of the waveform has been clipped off by detector diode, a rectifier.**
- **Recovered audio, after audio filtering, shown in blue.**

Military Electronics 1914

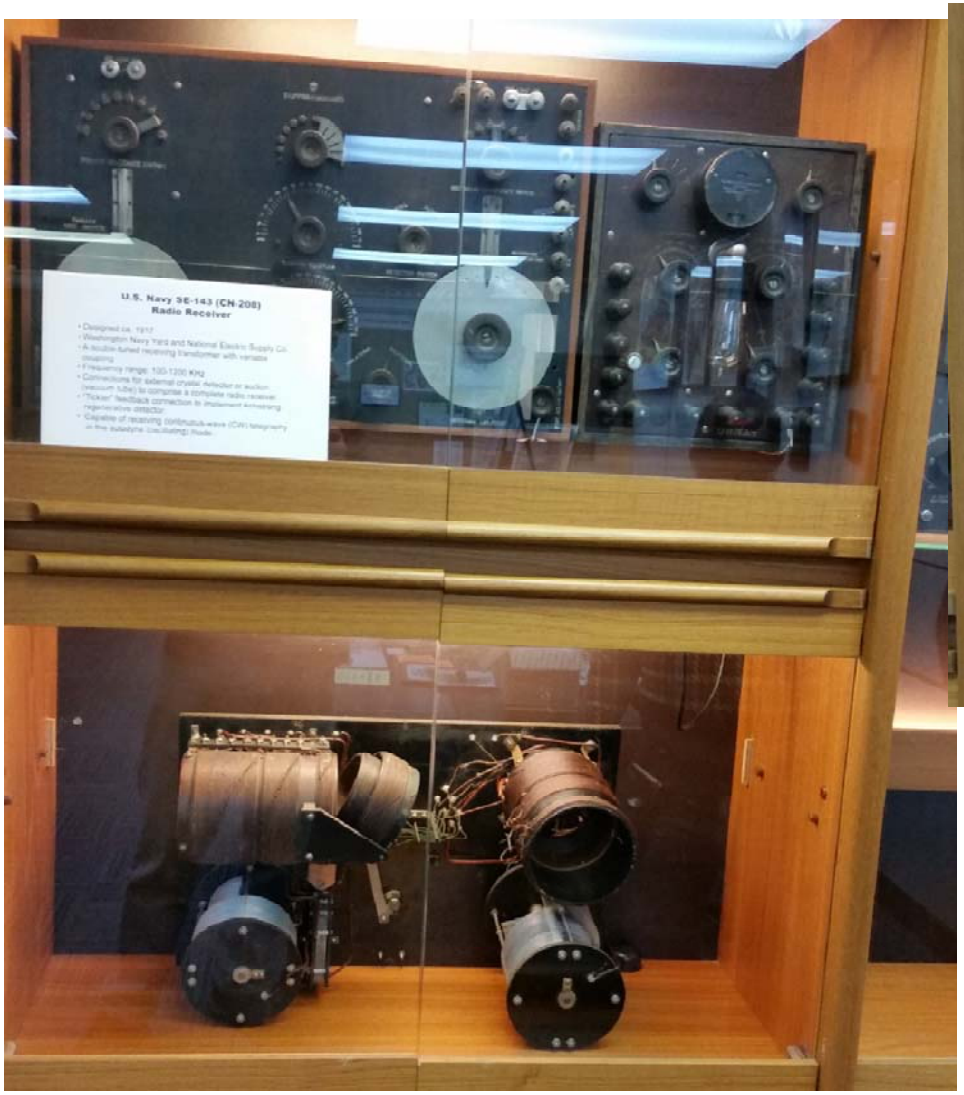
Spark transmitters and crystal sets

Navy Equipment at Belmar 1918
(Howeth)



Two audion control boxes
Receiver
2-stage audio amplifier

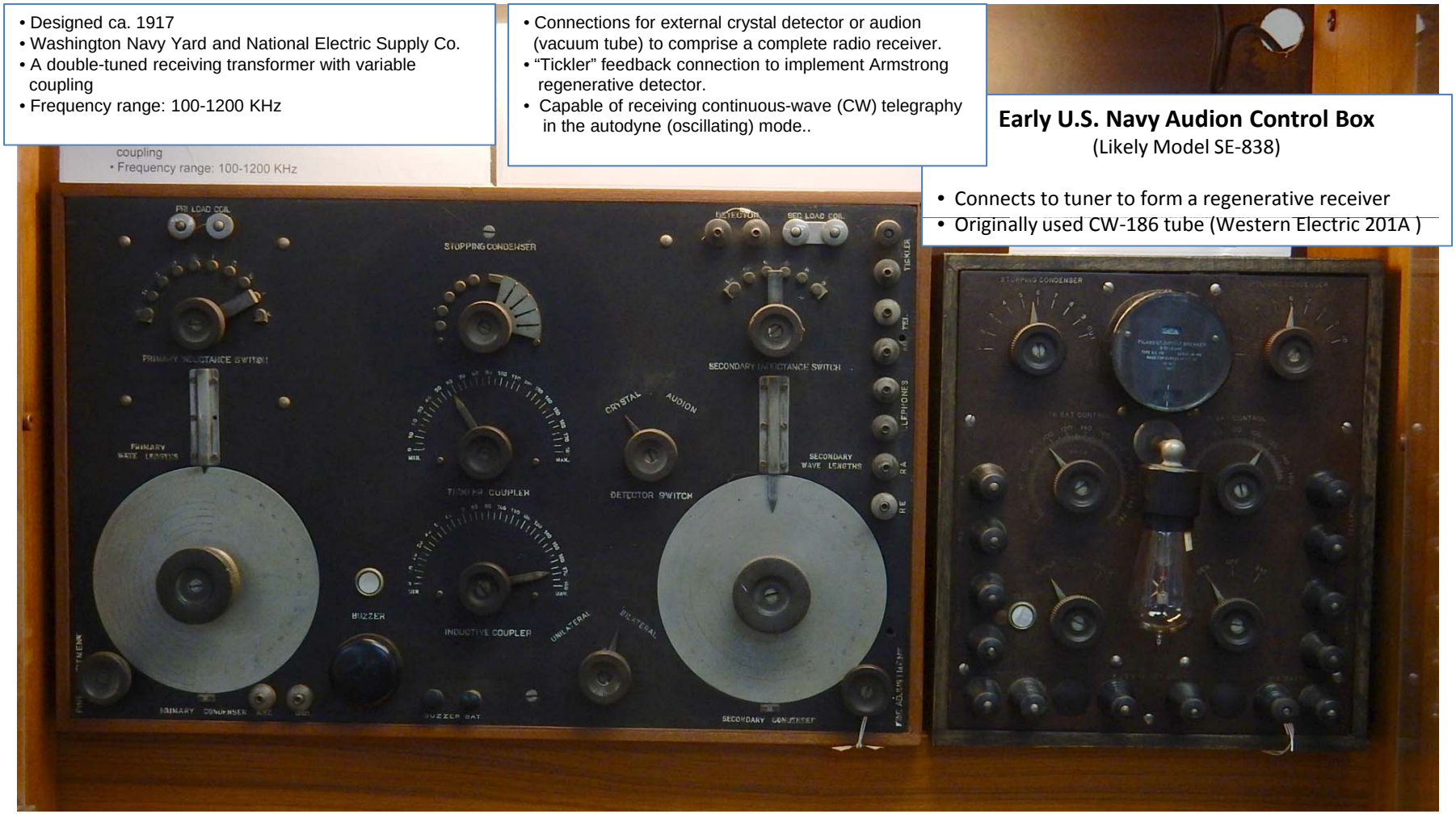
Navy Equipment at Belmar 2016



U.S. Navy SE-143 (CN-208)
Radio Receiver

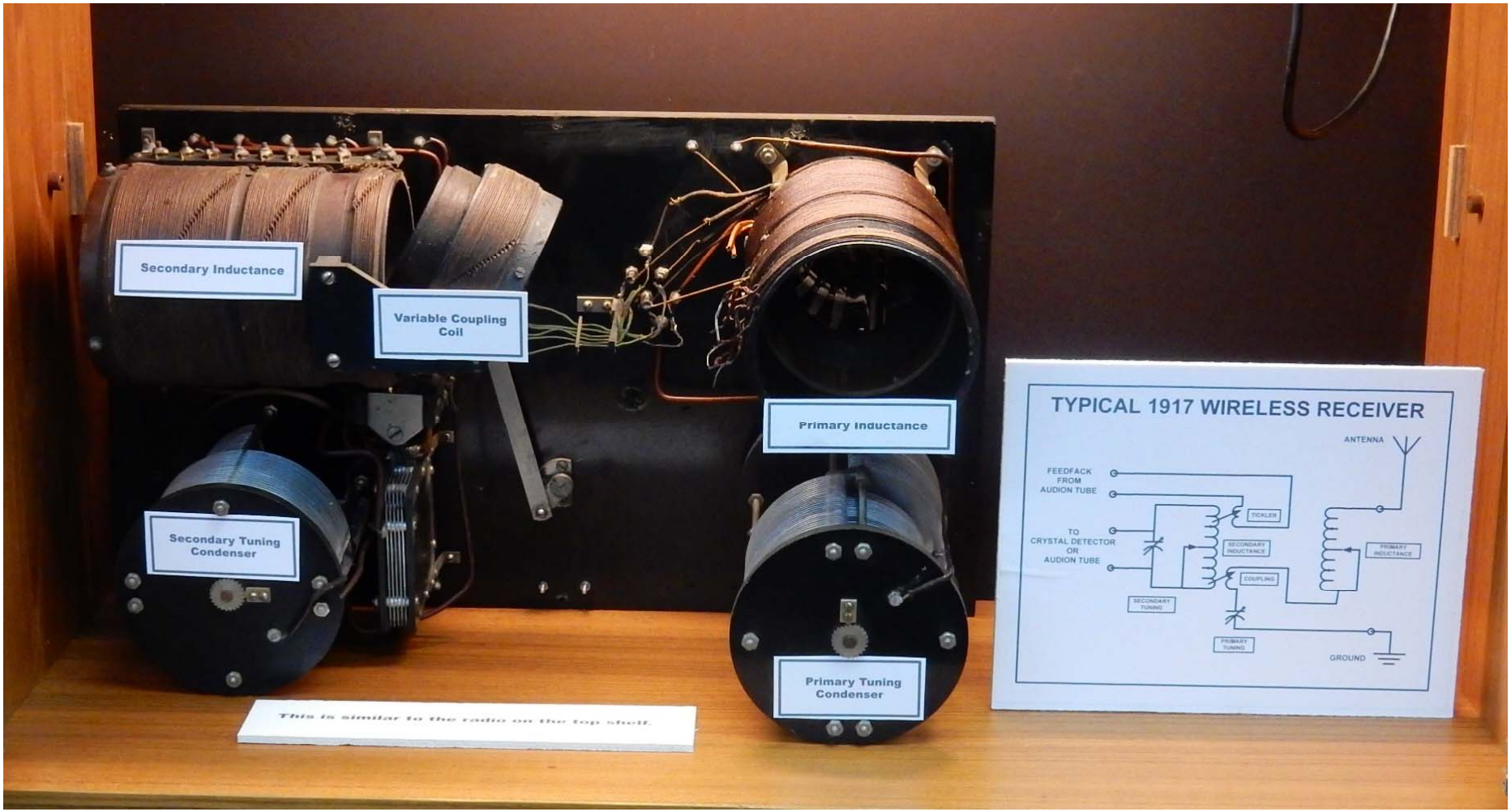
- Designed ca. 1917
- Washington Navy Yard and National Electric Supply Co.
- A double-tuned receiving transformer with variable coupling
- Frequency range: 100-1200 KHz

- Connections for external crystal detector or audion (vacuum tube) to comprise a complete radio receiver.
- "Tickler" feedback connection to implement Armstrong regenerative detector.
- Capable of receiving continuous-wave (CW) telegraphy in the autodyne (oscillating) mode..



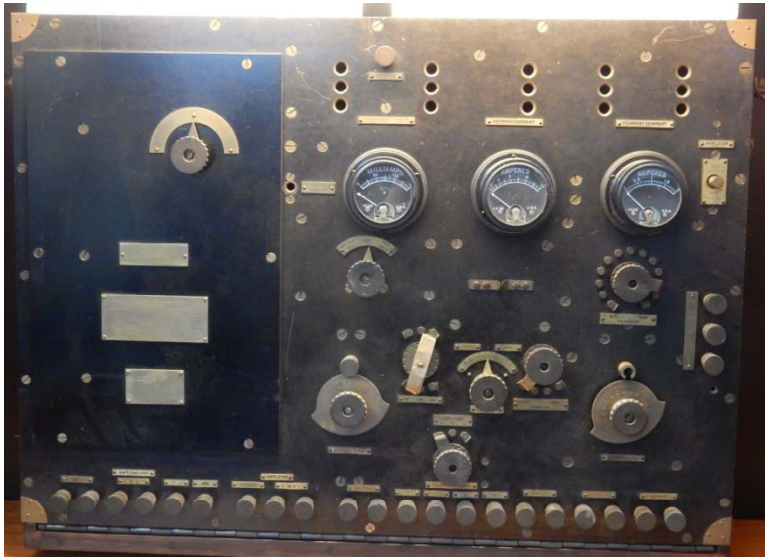
Early U.S. Navy Audion Control Box
(Likely Model SE-838)

- Connects to tuner to form a regenerative receiver
- Originally used CW-186 tube (Western Electric 201A)


Secondary Inductance
Variable Coupling Coil
Primary Inductance
Secondary Tuning Condenser
Primary Tuning Condenser
This is similar to the radio on the top shelf.
TYPICAL 1917 WIRELESS RECEIVER
ANTENNA
FEEDFACK FROM AUDION TUBE
TO CRYSTAL DETECTOR OR AUDION TUBE
TICKLER
SECONDARY INDUCTANCE
PRIMARY INDUCTANCE
COUPLING
SECONDARY TUNING
PRIMARY TUNING
GROUND

Military Electronics 1918

- Portable Continuous-Wave Transmitter-Receivers
- Radio Telephone Systems
- Long-Range Radio Telephone Transmitters
- Based on mass-produced vacuum tubes



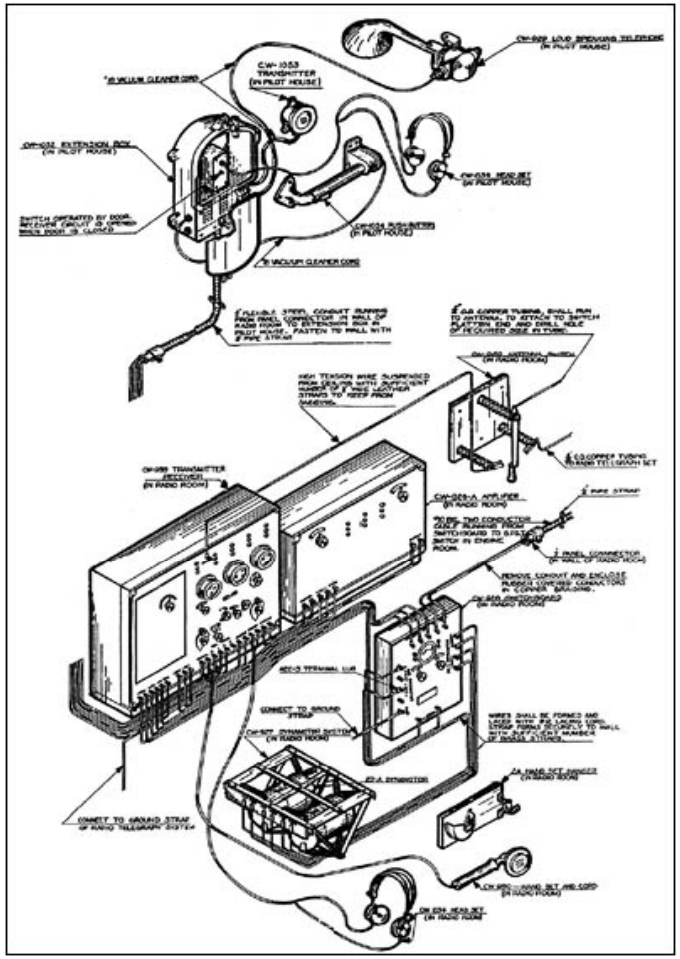
BC-32A CW Radio

CW-936

RADIO-TELEPHONE SYSTEM

”THE SUBCHASER SET”

- Designed by Western Electric
- First commercially produced radio-telephone system
- Mic and loudspeaker on the bridge for quick communications
- 2-tube AM transmitter
- 3-tube receiver
- Five preset frequencies 870-1270 KHz
- 3-tube audio amplifier
- “Loud-speaking telephone”



EARLY U.S. MILITARY VACUUM TUBES

Early Broadcasting Demos

1921 Westinghouse RC and Aeriola Junior

Early Broadcasting Demos

1924 Atwater Kent Model 20C

Operating Demos at RTM

- Morse Telegraph – Two Stations w/poles and insulators
- Code-practice sets – Titanic Spark, Modern CW
- Candle-stick dial telephone
- Spark Transmitter
- Tuning-in Demo
- “Original” Armstrong Regen
- Virtual Ether
- Westinghouse RC
- Atwater Kent Model 20 C
- 1930’s Philco Console
- Hammarlund SP-600
- R-390A with modulation-monitor scope

Operating Demos at RTM

- Edison Gramophone
- Victrola
- Edison Diamond Disk machine
- Several 45's (Phil wrote the book.)
- Mono Hi-Fi – Fisher Tuner & Preamp, Heathkit Williamson amp, Altec Duplex speaker in Klipsch corner cabinet
- RCA 630 TV
- Dumont 21" TV – 1948
- ADSB Virtual Radar
- 1939 Philco console w/ Mystery Control (wireless remote)
- EE-8 field phones via BD-71 switchboard
- BC-348 receiver
- WWII Navy moral receiver

“Cable Radio” at RTM