A Brief History of Communications

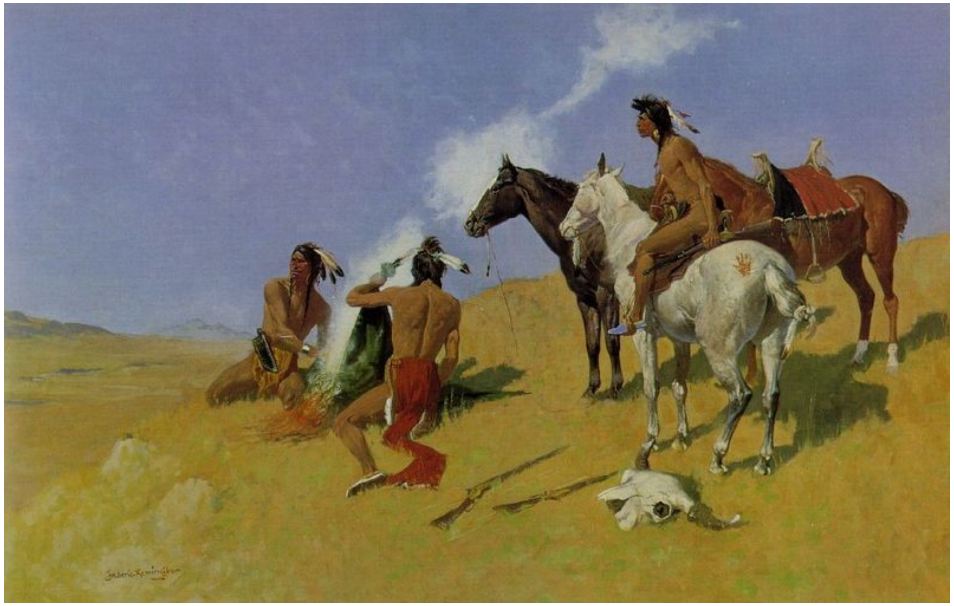
Paul Sutton

4th March 2014

ICTP School on Applications of Open Spectrum and White Spaces Technologies

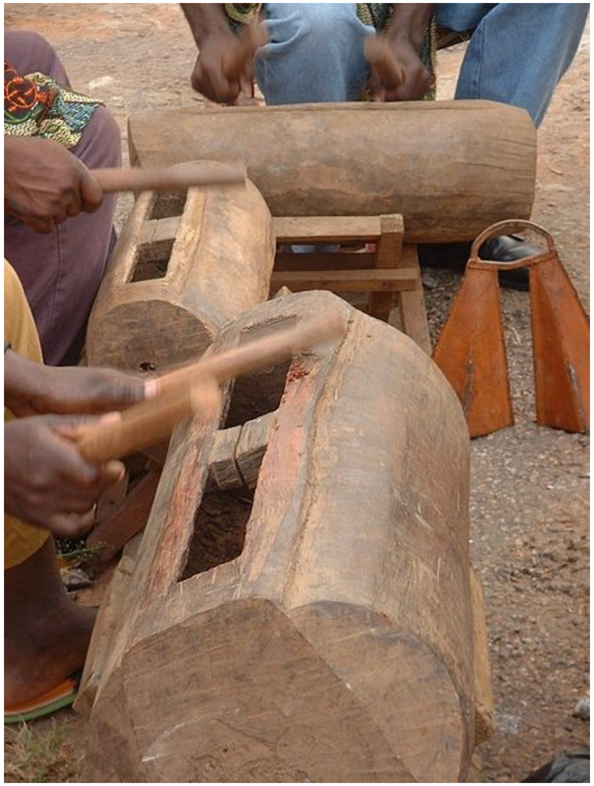
Software Radio Systems

CTVR the telecommunications research centre

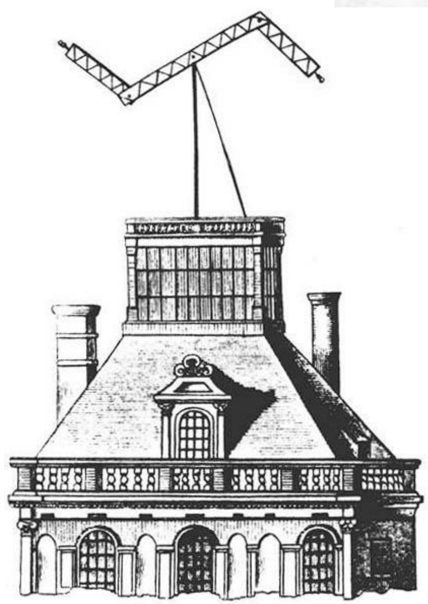


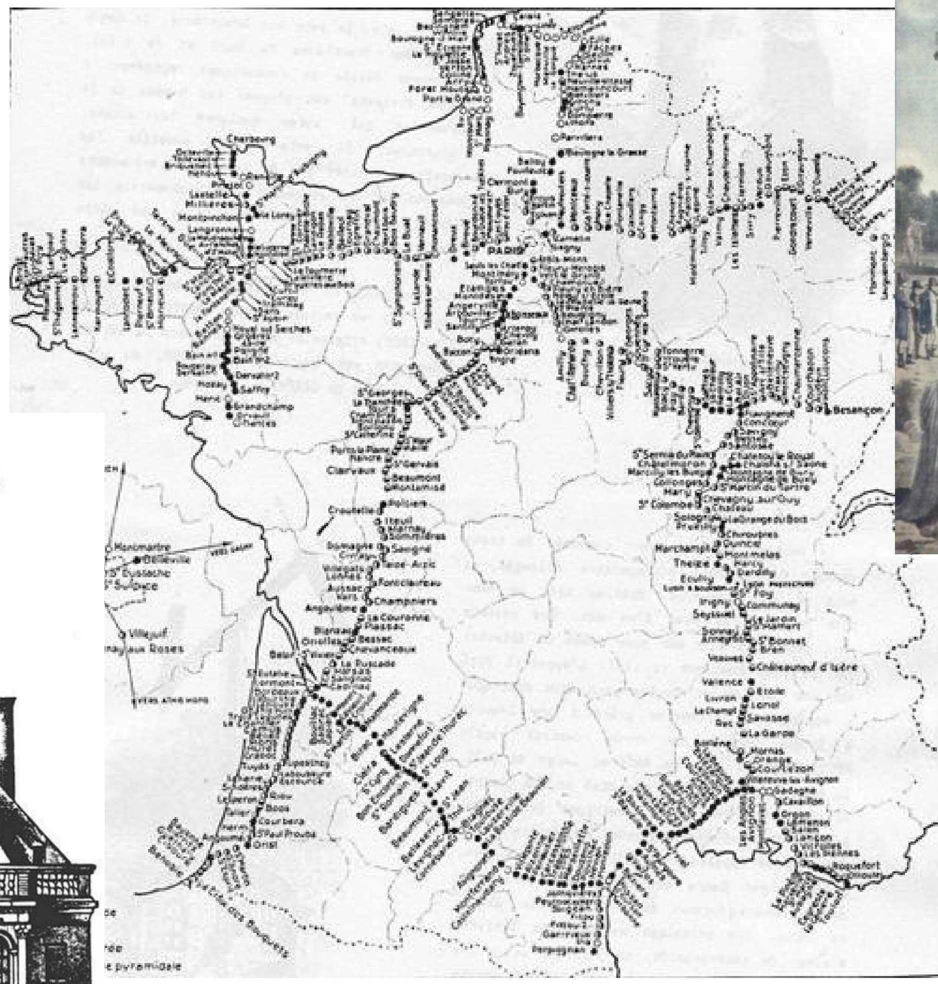
http://roborant42.appspot.com/show/entry/2031

Location	Modern Name	Altitude (m)	Distance (km)
Troy	Troy	100	0
Mt. Ida	Kaz Dagi	1774	55
Lemnos	Skopia at Limnos	430	154
Mt. Athos	Athos	2033	70
Macistus	Kandilion at Euboea	1209	177
Messapius	Ktipas	1020	30
Cithaeron	Elatias	1410	25
Mt. Aegiplanetus	Mt. Jeraneia	1370	30
Arachnaean	Hgt Arna	1199	50
Mycenae	Mycenae	150	20



http://www.philtulga.com/Drum%20Language.html





Software Radio Systems

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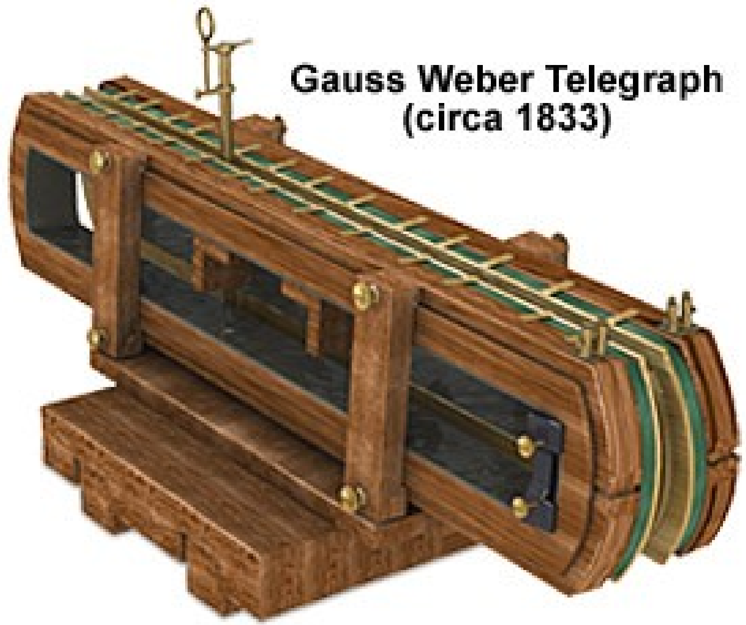
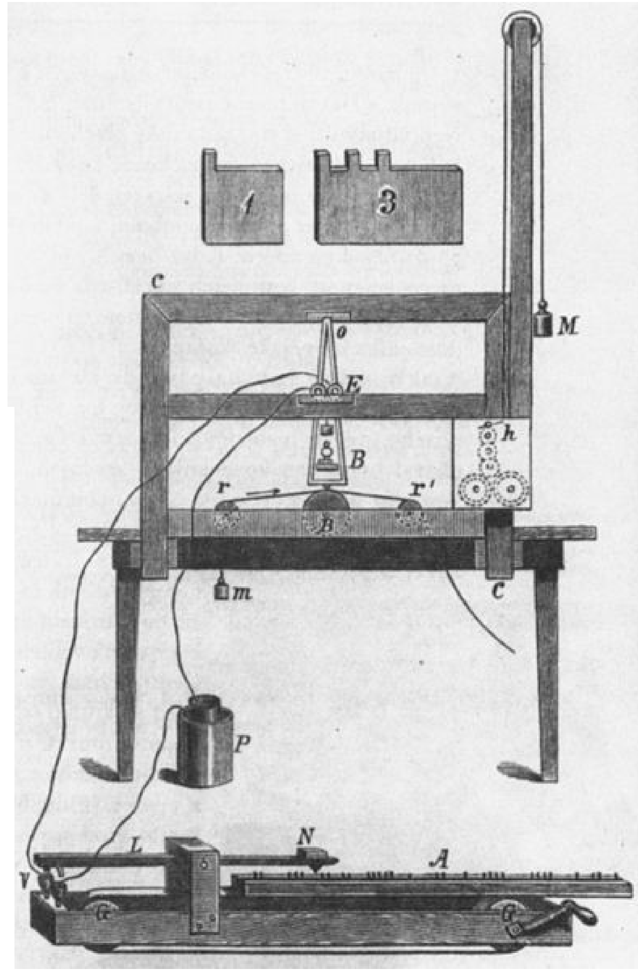
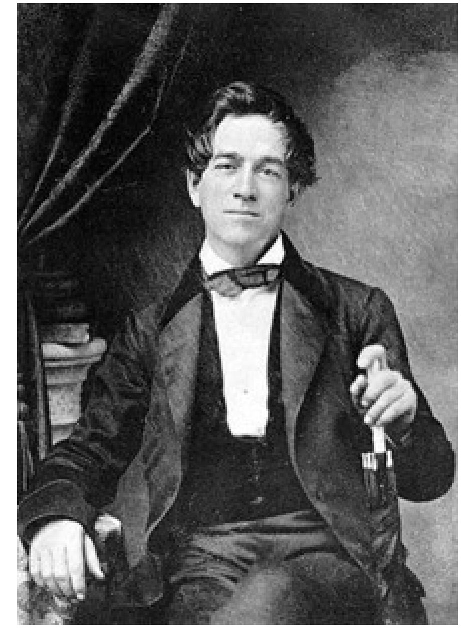

Gauss Weber Telegraph
(circa 1833)

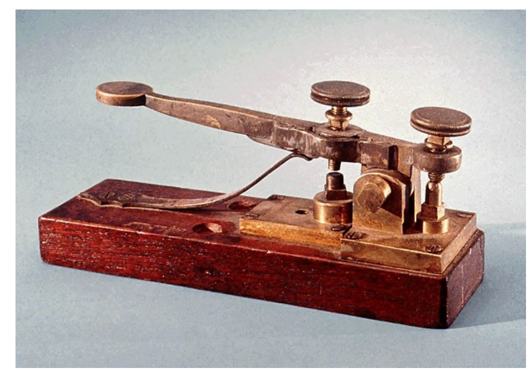
International Morse Code

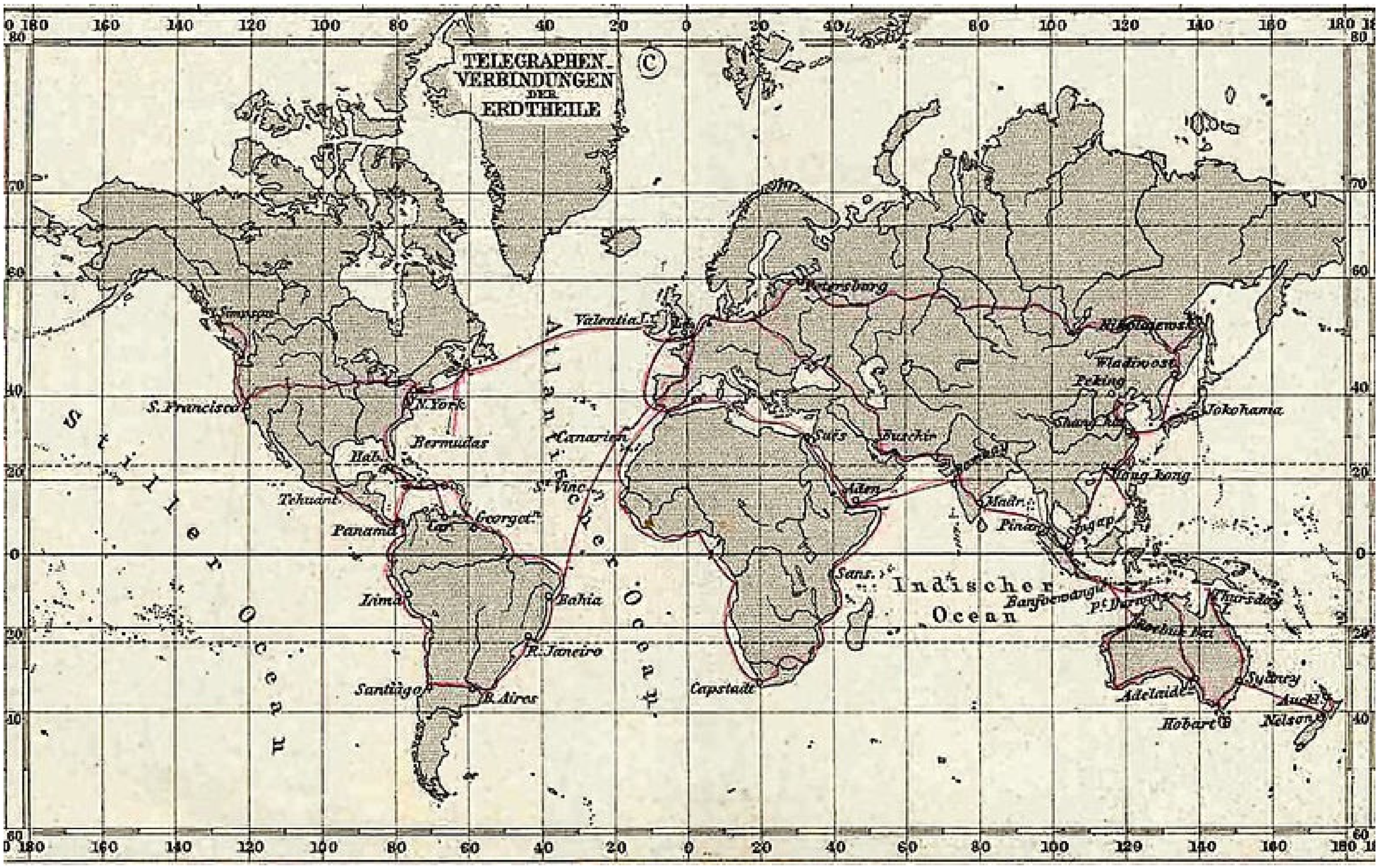
1. The length of a dot is one unit.
2. A dash is three units.
3. The space between parts of the same letter is one unit.
4. The space between letters is three units.
5. The space between words is seven units.

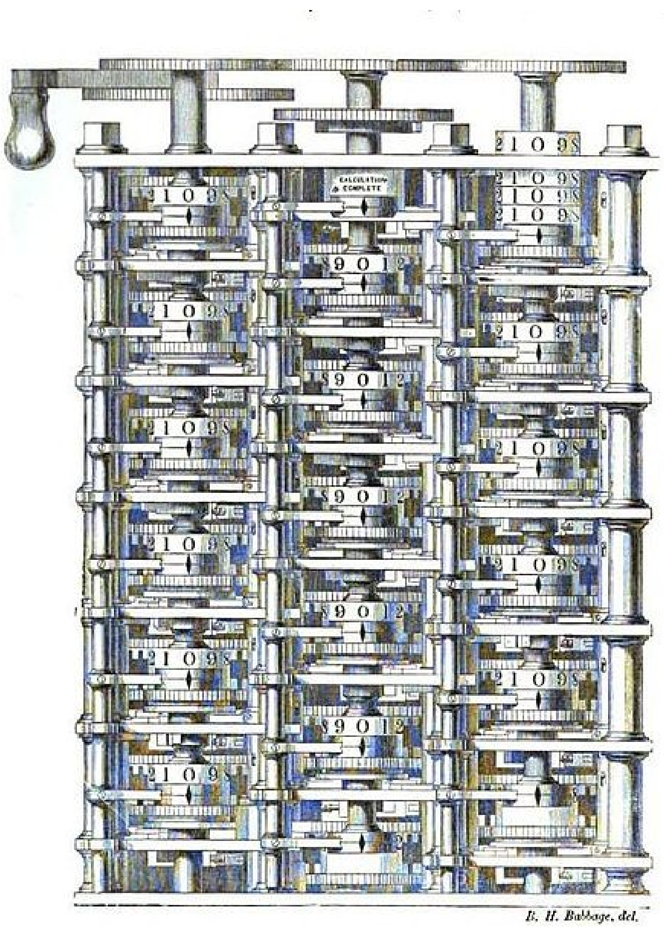
A	• ▬	U	• • ▬
B	▬ • • •	V	• • • ▬
C	▬ • ▬ •	W	• ▬ ▬
D	▬ • •	X	▬ • • ▬
E	•	Y	▬ • ▬ ▬
F	• • ▬ •	Z	▬ ▬ • •
G	▬ ▬ •		
H	• • • •		
I	• •		
J	• ▬ ▬ ▬		
K	▬ • ▬	1	• ▬ ▬ ▬ ▬
L	• ▬ • •	2	• • ▬ ▬ ▬
M	▬ ▬	3	• • • ▬ ▬
N	▬ •	4	• • • • ▬
O	▬ ▬ ▬	5	• • • • •
P	• ▬ ▬ •	6	▬ • • • •
Q	▬ ▬ • ▬	7	▬ ▬ • • •
R	• ▬ •	8	▬ ▬ ▬ • •
S	• • •	9	▬ ▬ ▬ ▬ •
T	▬	0	▬ ▬ ▬ ▬ ▬

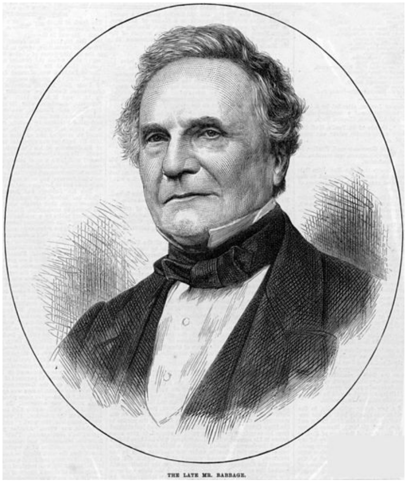


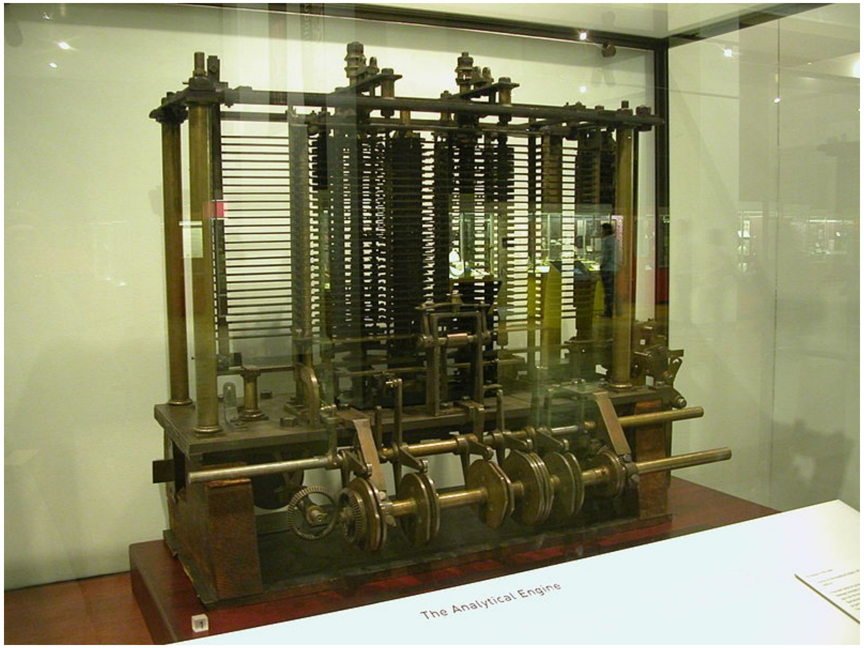





TELEGRAPHEN-
VERBINDUNGEN
DER
ERDTHEILE
Valentia
N.York
Bermudas
S.Francisco
Panama
Lima
Bahia
R.Janeiro
Santiago
B.Aires
Capstadt
Aden
Petersburg
Peking
Yokohama
Hong kong
Sydney
Adelaide
Hobart
Nelson
Indischer
Ocean


B. H. Babbage, del.

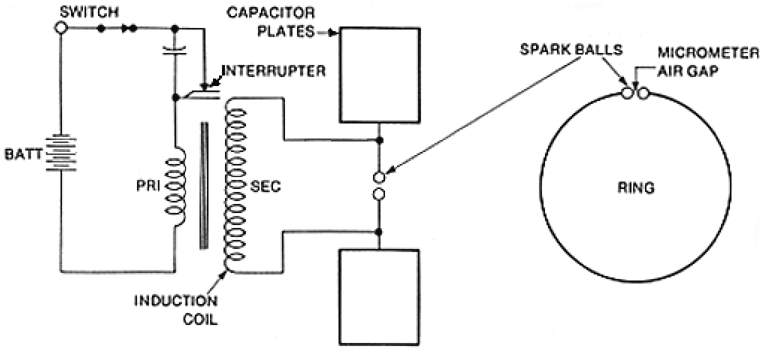

THE LATE MR. BABBAGE.

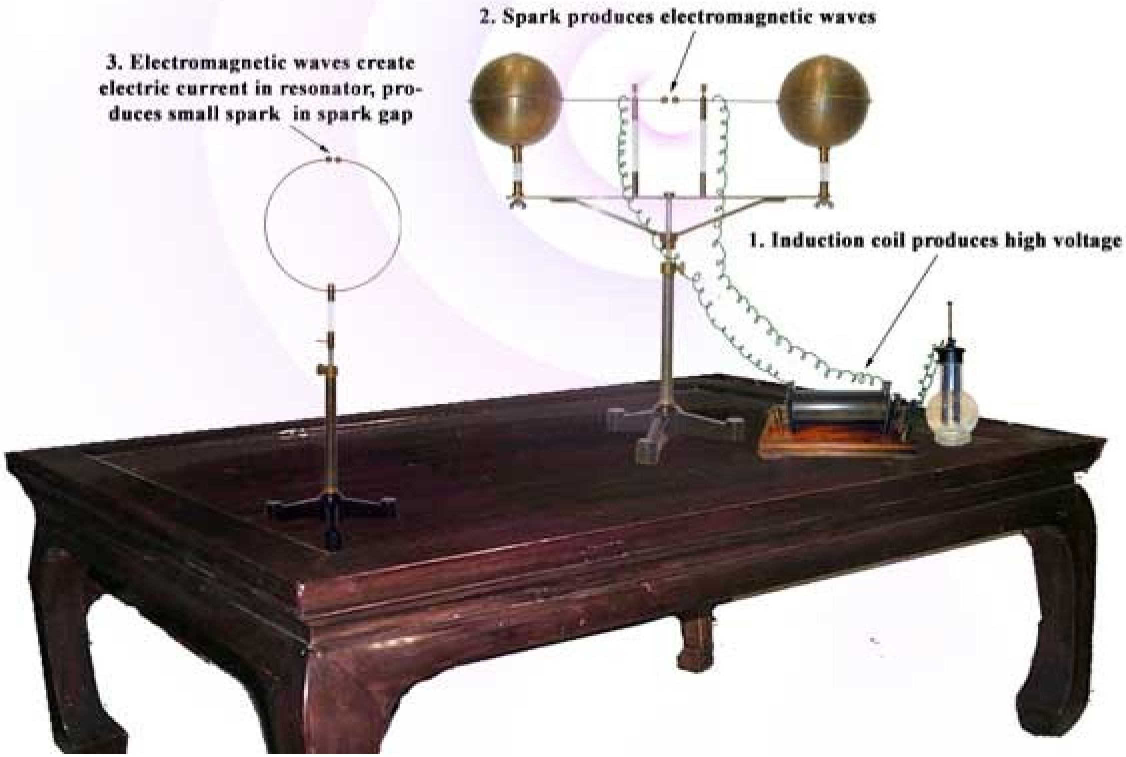

The Analytical Engine

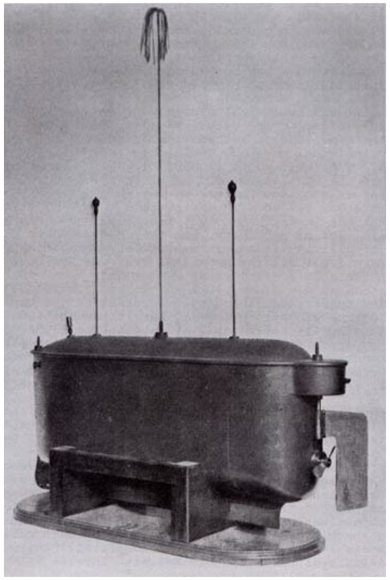
Number of Operation	Nature of Operation	Variables acted upon	Variables receiving results	Indication of change in the value on any Variable	Statement of Results
1	×	$^1V_2 \times {}^1V_3$	$^1V_4, {}^1V_5, {}^1V_6$	$\left\{\begin{matrix} ^1V_2 = {}^1V_2 \\ ^1V_3 = {}^1V_3 \end{matrix}\right\}$	$= 2n$
2	−	$^1V_4 - {}^1V_1$	$^2V_4$	$\left\{\begin{matrix} ^1V_4 = {}^2V_4 \\ ^1V_1 = {}^1V_1 \end{matrix}\right\}$	$= 2n - 1$
3	+	$^1V_5 + {}^1V_1$	$^2V_5$	$\left\{\begin{matrix} ^1V_5 = {}^2V_5 \\ ^1V_1 = {}^1V_1 \end{matrix}\right\}$	$= 2n + 1$
4	÷	$^2V_5 \div {}^2V_4$	$^1V_{11}$	$\left\{\begin{matrix} ^2V_5 = {}^0V_5 \\ ^2V_4 = {}^0V_4 \end{matrix}\right\}$	$= \frac{2n-1}{2n+1}$
5	÷	$^1V_{11} \div {}^1V_2$	$^2V_{11}$	$\left\{\begin{matrix} ^1V_{11} = {}^2V_{11} \\ ^1V_2 = {}^1V_2 \end{matrix}\right\}$	$= \frac{1}{2} \cdot \frac{2n-1}{2n+1}$
6	−	$^0V_{13} - {}^2V_{11}$	$^1V_{13}$	$\left\{\begin{matrix} ^2V_{11} = {}^0V_{11} \\ ^0V_{13} = {}^1V_{13} \end{matrix}\right\}$	$= -\frac{1}{2} \cdot \frac{2n-1}{2n+1} = A_0$
7	−	$^1V_3 - {}^1V_1$	$^1V_{10}$	$\left\{\begin{matrix} ^1V_3 = {}^1V_3 \\ ^1V_1 = {}^1V_1 \end{matrix}\right\}$	$= n - 1 (= 3)$
8	+	$^1V_2 + {}^0V_7$	$^1V_7$	$\left\{\begin{matrix} ^1V_2 = {}^1V_2 \\ ^0V_7 = {}^1V_7 \end{matrix}\right\}$	$= 2 + 0 = 2$
9	÷	$^1V_6 \div {}^1V_7$	$^3V_{11}$	$\left\{\begin{matrix} ^1V_6 = {}^1V_6 \\ ^0V_{11} = {}^3V_{11} \end{matrix}\right\}$	$= \frac{2n}{2} = A_1$
10	×	$^1V_{21} \times {}^3V_{11}$	$^1V_{12}$	$\left\{\begin{matrix} ^1V_{21} = {}^1V_{21} \\ ^3V_{11} = {}^3V_{11} \end{matrix}\right\}$	$= B_1 \cdot \frac{2n}{2} = B_1 A_1$
11	+	$^1V_{12} + {}^1V_{13}$	$^2V_{13}$	$\left\{\begin{matrix} ^1V_{12} = {}^0V_{12} \\ ^1V_{13} = {}^2V_{13} \end{matrix}\right\}$	$= -\frac{1}{2} \cdot \frac{2n-1}{2n+1} + B_1 \cdot \frac{2n}{2}$
12	−	$^1V_{10} - {}^1V_1$	$^2V_{10}$	$\left\{\begin{matrix} ^1V_{10} = {}^2V_{10} \\ ^1V_1 = {}^1V_1 \end{matrix}\right\}$	$= n - 2 (= 2)$
13	−	$^1V_6 - {}^1V_1$	$^2V_6$	$\left\{\begin{matrix} ^1V_6 = {}^2V_6 \\ ^1V_1 = {}^1V_1 \end{matrix}\right\}$	$= 2n - 1$
14	+	$^1V_1 + {}^1V_7$	$^2V_7$	$\left\{\begin{matrix} ^1V_1 = {}^1V_1 \\ ^1V_7 = {}^2V_7 \end{matrix}\right\}$	$= 2 + 1 = 3$
15	÷	$^2V_6 \div {}^2V_7$	$^1V_8$	$\left\{\begin{matrix} ^2V_6 = {}^2V_6 \\ ^2V_7 = {}^2V_7 \end{matrix}\right\}$	$= \frac{2n-1}{3}$
16	×	$^1V_8 \times {}^3V_{11}$	$^4V_{11}$	$\left\{\begin{matrix} ^1V_8 = {}^0V_8 \\ ^3V_{11} = {}^4V_{11} \end{matrix}\right\}$	$= \frac{2n}{2} \cdot \frac{2n-1}{3}$
17	−	$^2V_6 - {}^1V_1$	$^3V_6$	$\left\{\begin{matrix} ^2V_6 = {}^3V_6 \\ ^1V_1 = {}^1V_1 \end{matrix}\right\}$	$= 2n - 2$
18	+	$^1V_1 + {}^2V_7$	$^3V_7$	$\left\{\begin{matrix} ^2V_7 = {}^3V_7 \\ ^1V_1 = {}^1V_1 \end{matrix}\right\}$	$= 3 + 1 = 4$
19	÷	$^3V_6 \div {}^3V_7$	$^1V_9$	$\left\{\begin{matrix} ^3V_6 = {}^3V_6 \\ ^3V_7 = {}^3V_7 \end{matrix}\right\}$	$= \frac{2n-2}{4}$
20	×	$^1V_9 \times {}^4V_{11}$	$^5V_{11}$	$\left\{\begin{matrix} ^1V_9 = {}^0V_9 \\ ^4V_{11} = {}^5V_{11} \end{matrix}\right\}$	$= \frac{2n}{2} \cdot \frac{2n-1}{3} \cdot \frac{2n-2}{4} = A_3$
21	×	$^1V_{22} \times {}^5V_{11}$	$^0V_{12}$	$\left\{\begin{matrix} ^1V_{22} = {}^1V_{22} \\ ^0V_{12} = {}^2V_{12} \end{matrix}\right\}$	$= B_3 \cdot \frac{2n}{2} \cdot \frac{2n-1}{3} \cdot \frac{2n-2}{4} = B_3 A_3$
22	+	$^2V_{12} + {}^2V_{13}$	$^3V_{13}$	$\left\{\begin{matrix} ^2V_{12} = {}^0V_{12} \\ ^2V_{13} = {}^3V_{13} \end{matrix}\right\}$	$= A_0 + B_1 A_1 + B_3 A_3$
23	−	$^2V_{10} - {}^1V_1$	$^3V_{10}$	$\left\{\begin{matrix} ^2V_{10} = {}^3V_{10} \\ ^1V_1 = {}^1V_1 \end{matrix}\right\}$	$= n - 3 (= 1)$
					Here follows a repetition of Operations thirteen to twenty-three
24	+	$^4V_{13} + {}^0V_{24}$	$^1V_{24}$	$\left\{\begin{matrix} ^4V_{13} = {}^0V_{13} \\ ^0V_{24} = {}^1V_{24} \end{matrix}\right\}$	$= B_7$
25	+	$^1V_1 + {}^1V_3$	$^1V_3$	$\left\{\begin{matrix} ^1V_1 = {}^1V_1 \\ ^1V_3 = {}^1V_3 \\ ^5V_6 = {}^0V_6 \\ ^5V_7 = {}^0V_7 \end{matrix}\right.$	$= n + 1 = 4 + 1 = 5$ by a Variable-card. by a Variable-card.

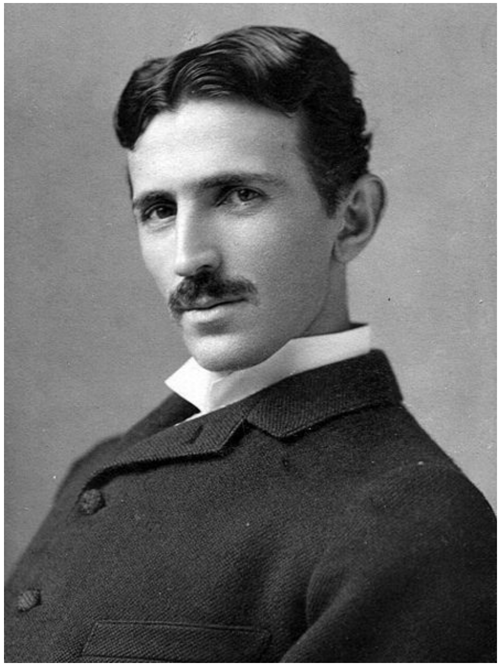
Number of Operation	Data			Working Variables										Result Variables			
	$^1V_1$	$^1V_2$	$^1V_3$	$^0V_4$	$^0V_5$	$^0V_6$	$^0V_7$	$^0V_8$	$^0V_9$	$^0V_{10}$	$^0V_{11}$	$^0V_{12}$	$^0V_{13} \cdots$	$^1V_{21}$	$^1V_{22}$	$^1V_{23}$	$^0V_{24} \cdots$
	○ 0 0 1	○ 0 0 2	○ 0 0 4	○ 0 0 0	○ 0 0 0	○ 0 0 0	○ 0 0 0	○ 0 0 0	○ 0 0 0	○ 0 0 0	○ 0 0 0	○ 0 0 0	○ 0 0 0	○ B is a dec. fract.	○ B is a dec. fract.	○ B is a dec. fract.	○ 0 0 0
	$\boxed{1}$	$\boxed{2}$	$\boxed{n}$	$\boxed{}$	$\boxed{}$	$\boxed{}$	$\boxed{}$	$\boxed{}$	$\boxed{}$	$\boxed{}$	$\boxed{}$	$\boxed{}$	$\boxed{}$	$\boxed{B_1}$	$\boxed{B_3}$	$\boxed{B_5}$	$\boxed{B_7}$
1	......	2	n	$2n$	$2n$	$2n$											
2	1	......	......	$2n - 1$													
3	1	......	......	......	$2n + 1$												
4	......	......	......	0	0	......	......	......	......	......	$\frac{2n-1}{2n+1}$						
5	......	2	......	......	......	......	......	......	......	......	$\frac{1}{2} \cdot \frac{2n-1}{2n+1}$						
6	......	......	......	......	......	......	......	......	......	......	0	......	$= -\frac{1}{2} \cdot \frac{2n-1}{2n+1} = A_0$				
7	1	......	n	......	......	......	......	......	......	$n - 1$							
8	......	2	......	......	......	......	2										
9	......	......	......	......	......	$2n$	2	......	......	......	$\frac{2n}{2} = A_1$						
10	......	......	......	......	......	......	......	......	......	......	$\frac{2n}{2} = A_1$	$B_1 \cdot \frac{2n}{2} = B_1 A_1$	......	B_1			
11	......	......	......	......	......	......	......	......	......	......	......	0	$\left\{-\frac{1}{2} \cdot \frac{2n-1}{2n+1} + B_1 \cdot \frac{2n}{2}\right\}$				
12	1	......	......	......	......	......	......	......	......	$n - 2$							
13	1	......	......	......	......	$2n - 1$											
14	1	......	......	......	......	......	3										
15	......	......	......	......	......	$2n - 1$	3	$\frac{2n-1}{3}$									
16	......	......	......	......	......	......	......	0	......	......	$\frac{2n}{2} \cdot \frac{2n-1}{3}$						
17	1	......	......	......	......	$2n - 2$											
18	1	......	......	......	......	......	4										
19	......	......	......	......	......	$2n - 2$	4	......	$\frac{2n-2}{4}$	......							
20	......	......	......	......	......	......	......	......	0		$\left\{\frac{2n}{2} \cdot \frac{2n-1}{3} \cdot \frac{2n-2}{4}\right\} = A_3$						
21	......	......	......	......	......	......	......	......	......	......	0	$B_3 A_3$	......	......	B_3		
22	......	......	......	......	......	......	......	......	......	......	......	0	$\{A_0 + B_1 A_1 + B_3 A_3\}$				
23	1	......	......	......	......	......	......	......	......	$n - 3$							
24	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	B_7
25	1	......	$n + 1$	......	......	0	0										

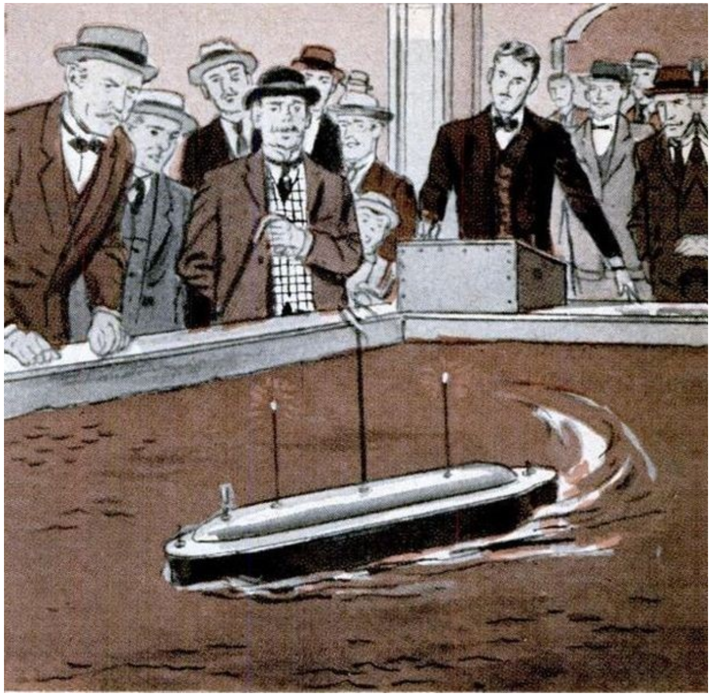
Name	Integral equations	Differential equations
Gauss's law	$\oiint_{\partial\Omega} \mathbf{E} \cdot \mathrm{d}\mathbf{S} = \frac{1}{\varepsilon_0} \iiint_{\Omega} \rho \, \mathrm{d}V$	$\nabla \cdot \mathbf{E} = \frac{\rho}{\varepsilon_0}$
Gauss's law for magnetism	$\oiint_{\partial\Omega} \mathbf{B} \cdot \mathrm{d}\mathbf{S} = 0$	$\nabla \cdot \mathbf{B} = 0$
Maxwell–Faraday equation (Faraday's law of induction)	$\oint_{\partial\Sigma} \mathbf{E} \cdot \mathrm{d}\boldsymbol{\ell} = -\frac{d}{dt} \iint_{\Sigma} \mathbf{B} \cdot \mathrm{d}\mathbf{S}$	$\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t}$
Ampère's circuital law (with Maxwell's correction)	$\oint_{\partial\Sigma} \mathbf{B} \cdot \mathrm{d}\boldsymbol{\ell} = \mu_0 \iint_{\Sigma} \left(\mathbf{J} + \varepsilon_0 \frac{\partial \mathbf{E}}{\partial t} \right) \cdot \mathrm{d}\mathbf{S}$	$\nabla \times \mathbf{B} = \mu_0 \left(\mathbf{J} + \varepsilon_0 \frac{\partial \mathbf{E}}{\partial t} \right)$


SWITCH
CAPACITOR PLATES
INTERRUPTER
SPARK BALLS
MICROMETER AIR GAP
BATT
PRI
SEC
RING
INDUCTION COIL


2. Spark produces electromagnetic waves
3. Electromagnetic waves create electric current in resonator, produces small spark in spark gap
1. Induction coil produces high voltage

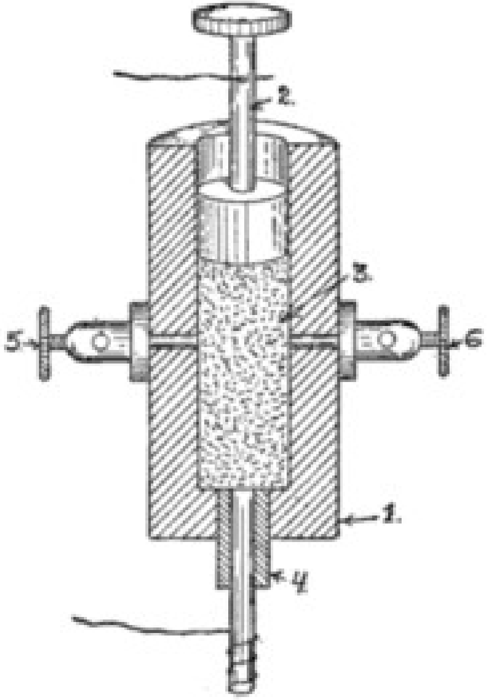


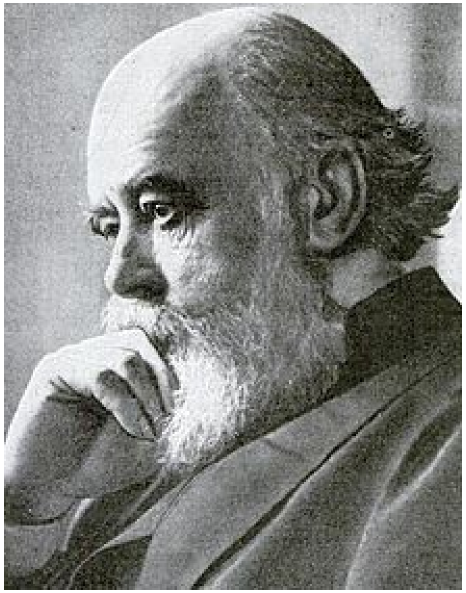


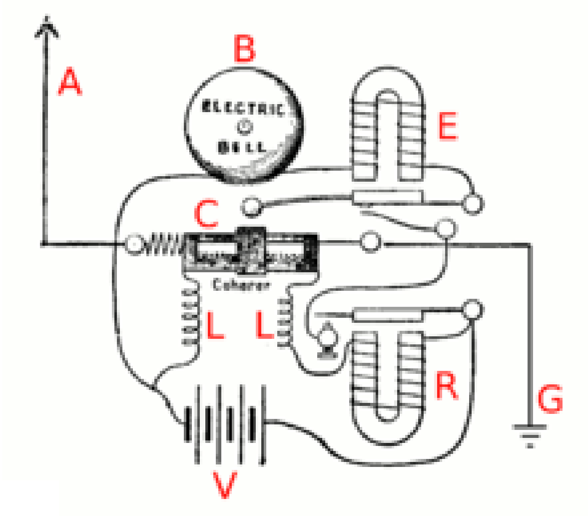


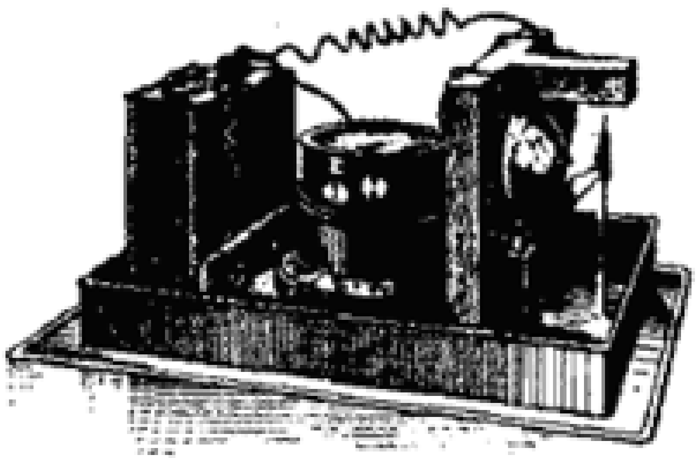
SRS Software Radio Systems

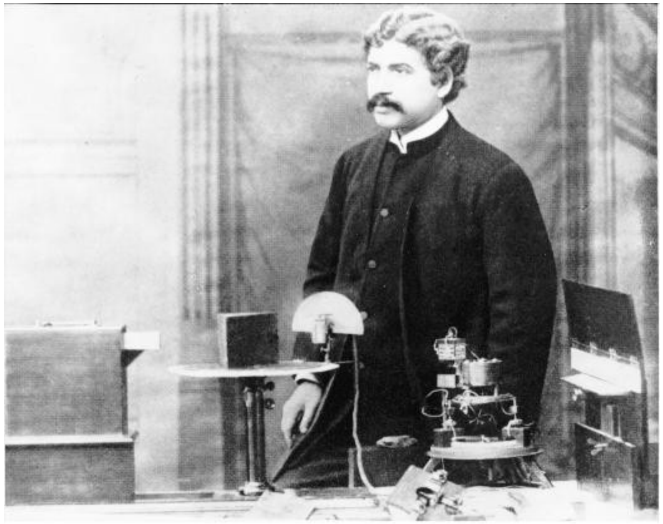
CTVR the telecommunications research centre

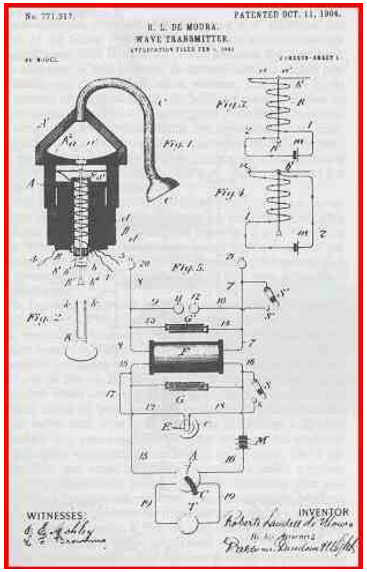

2.
3.
5
6
1.
4

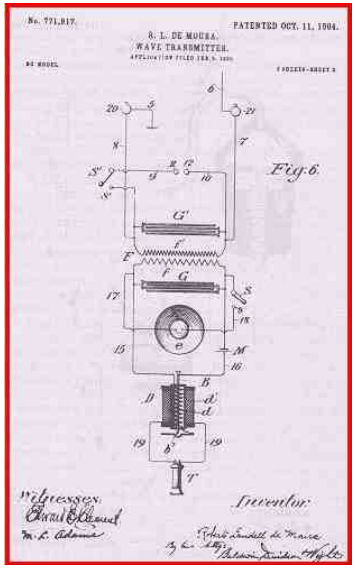


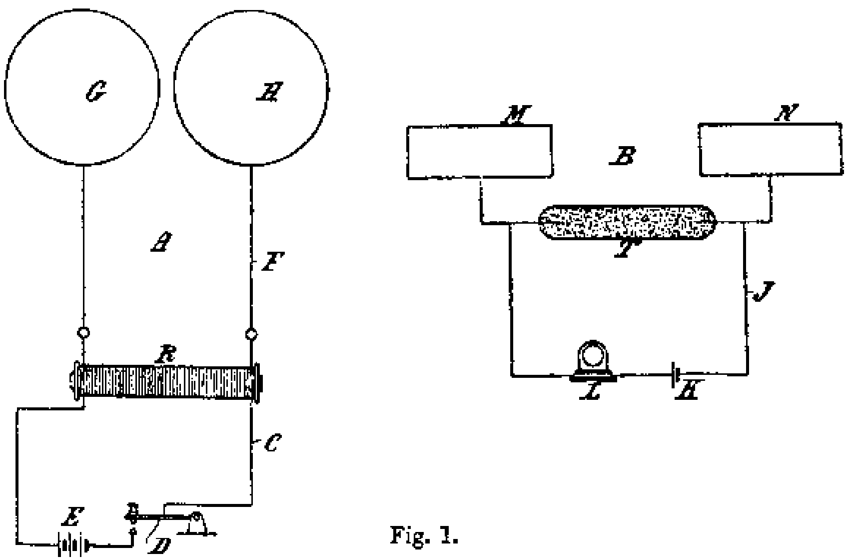

A
B
ELECTRIC
BELL
E
C
Coherer
L
L
R
G
V






No. 771,917.
PATENTED OCT. 11, 1904.
R. L. DE MOURA.
WAVE TRANSMITTER.
Fig. 1.
Fig. 3.
Fig. 4.
Fig. 5.
WITNESSES:
INVENTOR


No. 771,917.
PATENTED OCT. 11, 1904.
R. L. DE MOURA.
WAVE TRANSMITTER.
Fig. 6.
Witnesses:
Inventor:



G
H
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R
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D
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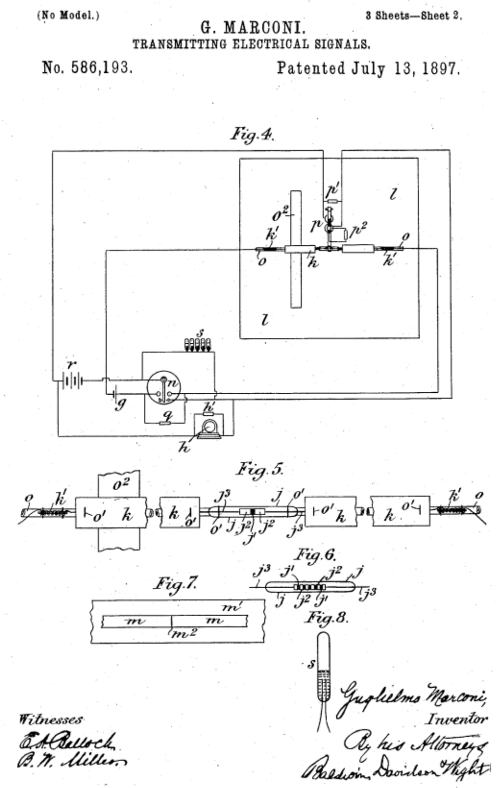
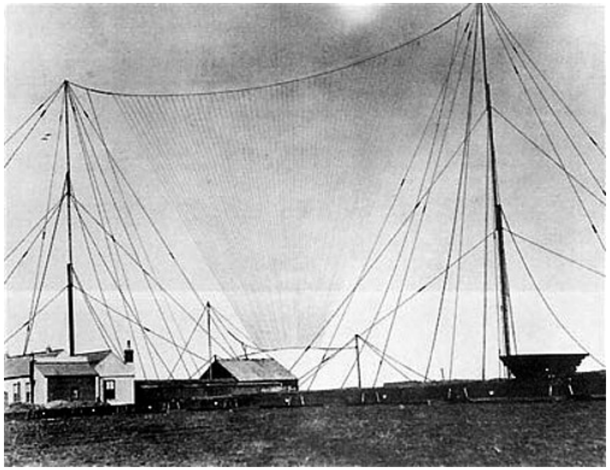
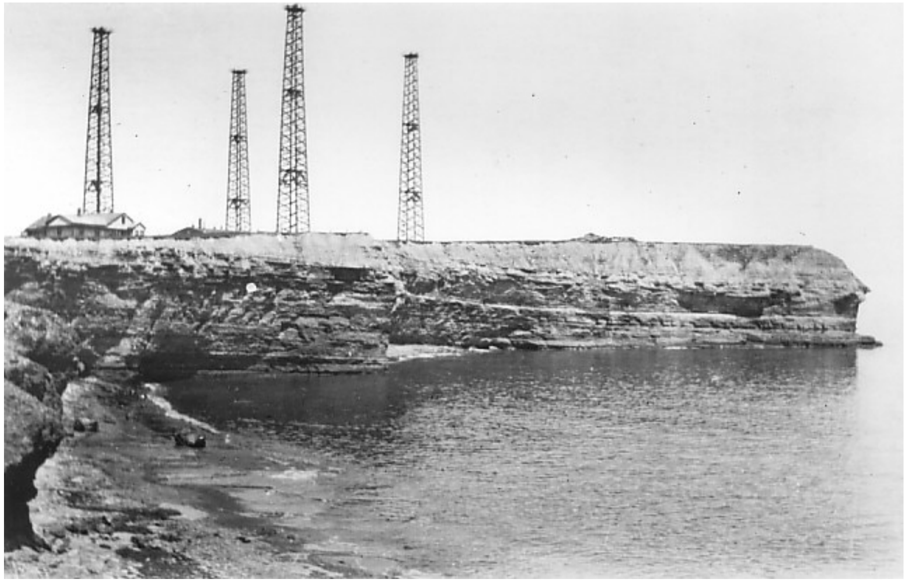
N
B
T
J
L
K

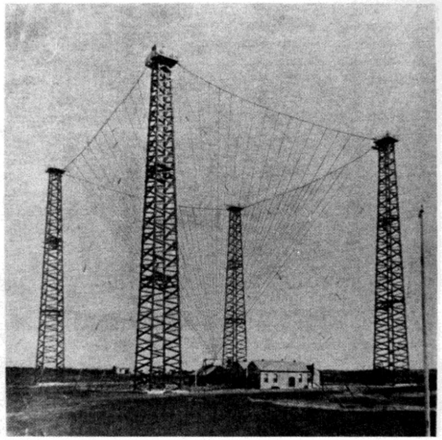
Fig. 1.



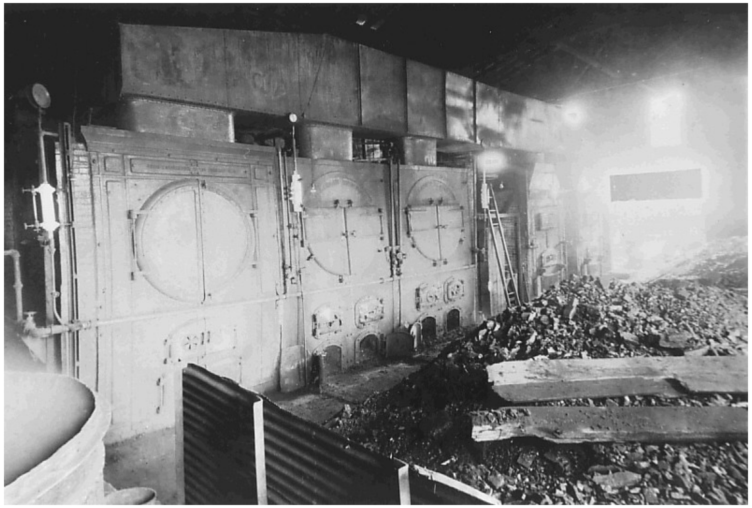
(No Model.)
3 Sheets—Sheet 2.
G. MARCONI.
TRANSMITTING ELECTRICAL SIGNALS.
No. 586,193.
Patented July 13, 1897.
Fig. 4.
Fig. 5.
Fig. 6.
Fig. 7.
Fig. 8.
Witnesses
Inventor

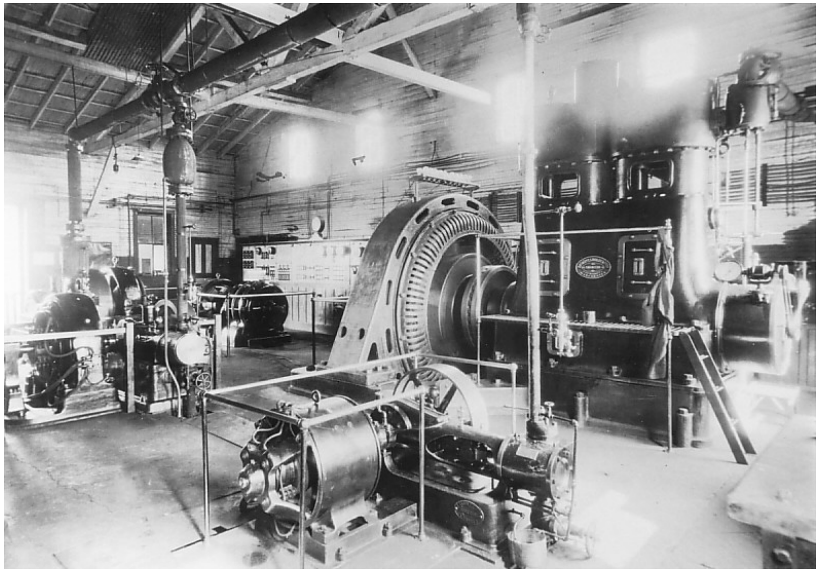


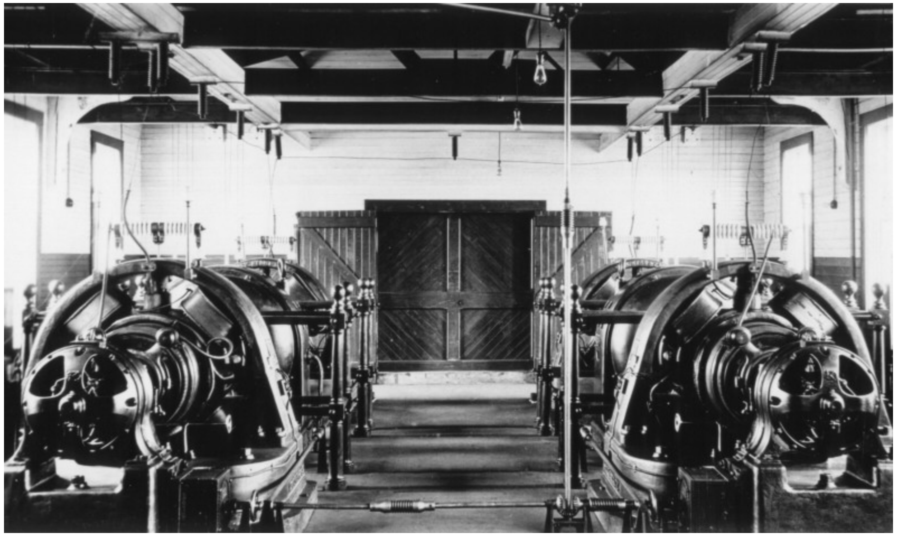


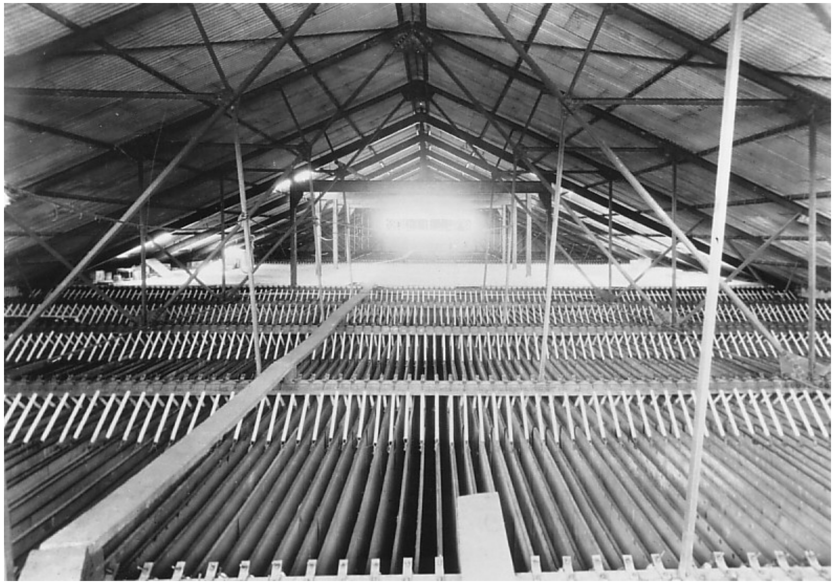


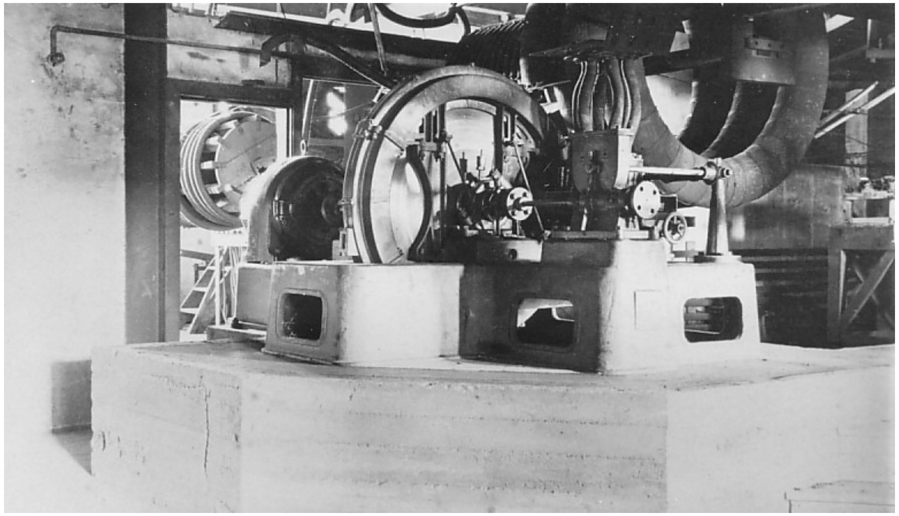
Marconi station at Poldhu, Cornwall, England, about 1905. The four wooden towers support a network of wires which converge to a point just above the transmitting and receiving buildings between the towers.

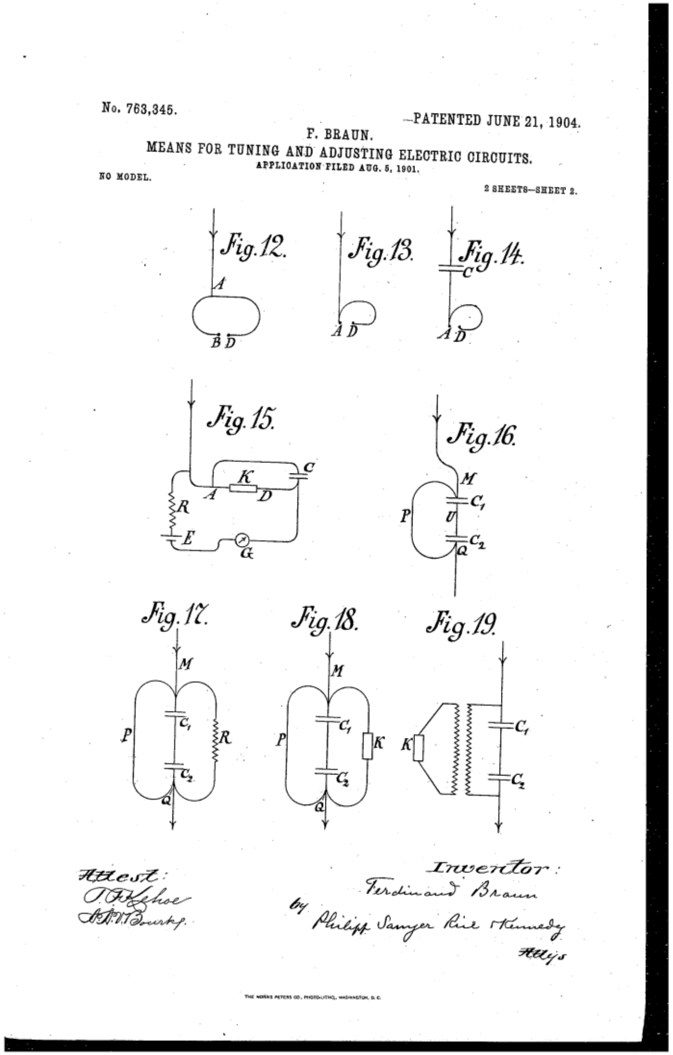


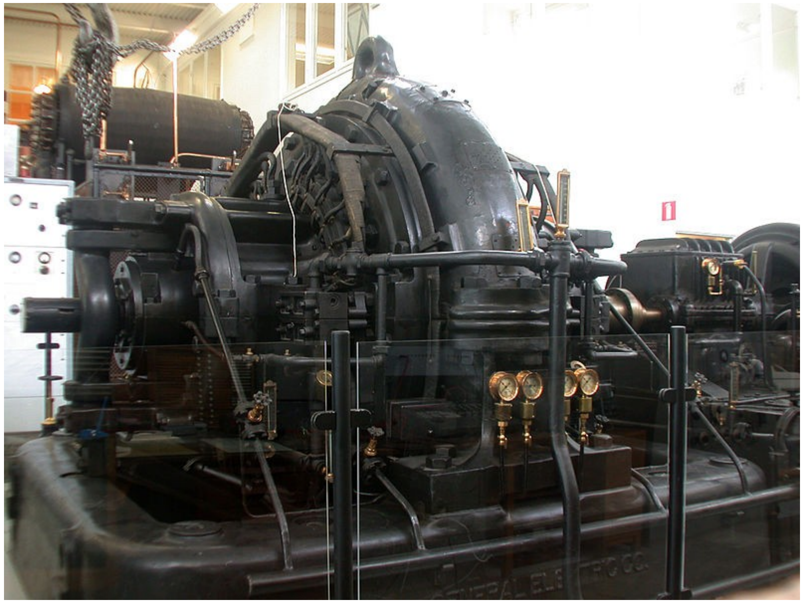


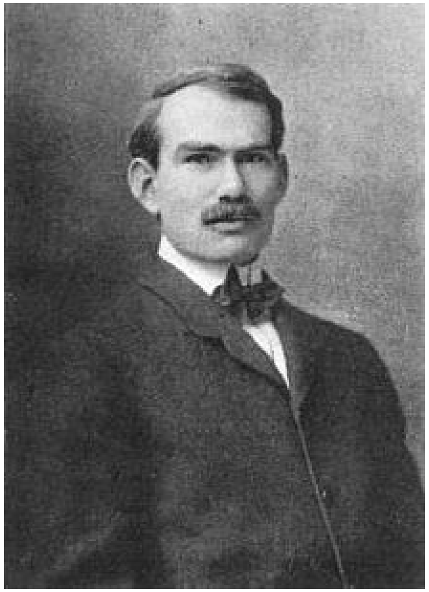


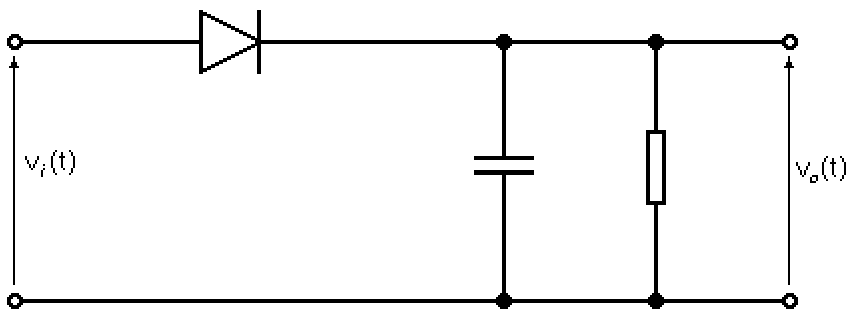




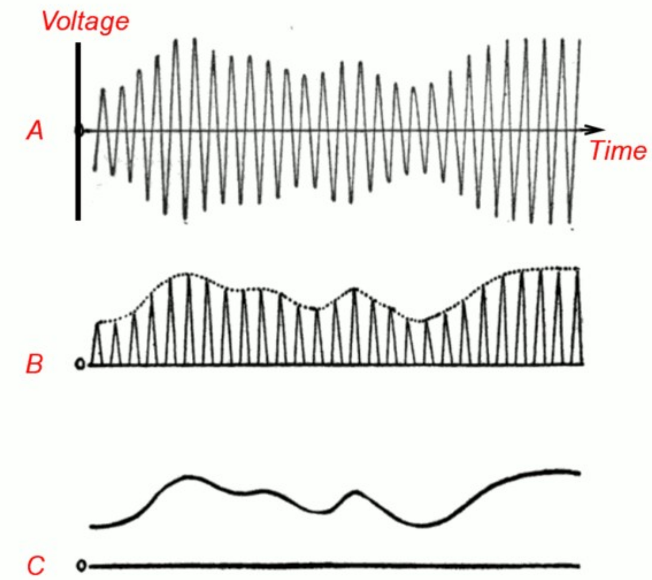

No. 763,345.
PATENTED JUNE 21, 1904.
F. BRAUN.
MEANS FOR TUNING AND ADJUSTING ELECTRIC CIRCUITS.
APPLICATION FILED AUG. 5, 1901.
NO MODEL.
2 SHEETS—SHEET 2.
Fig. 12.
Fig. 13.
Fig. 14.
Fig. 15.
Fig. 16.
Fig. 17.
Fig. 18.
Fig. 19.
Attest:
Inventor:
Ferdinand Braun
by Philipp Sawyer Rice & Kennedy
Att'ys



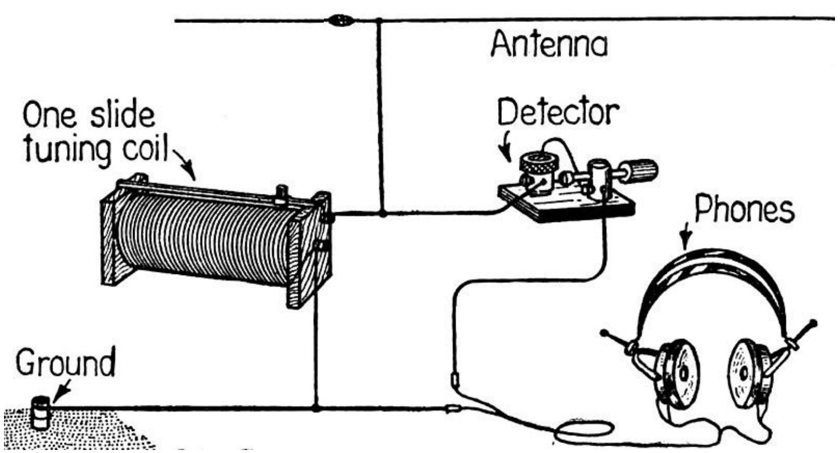




v_i(t)
v_o(t)



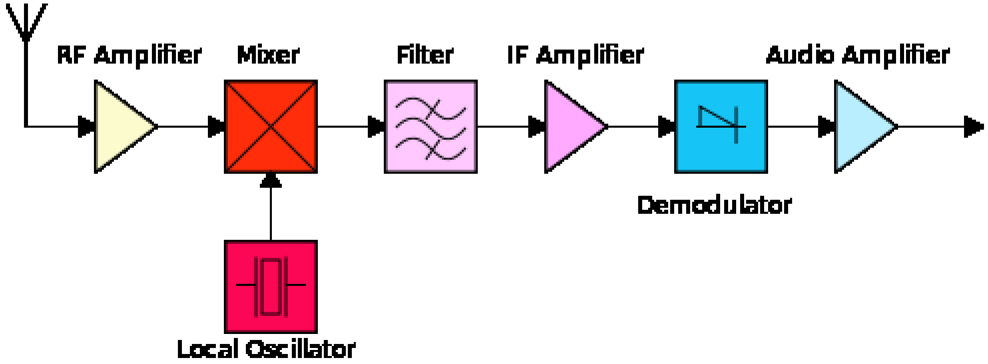
Voltage
A
Time
B
C



Antenna
One slide
tuning coil
Detector
Phones
Ground


EZ80


EDWIN H. ARMSTRONG


RF Amplifier
Mixer
Filter
IF Amplifier
Audio Amplifier
Demodulator
Local Oscillator

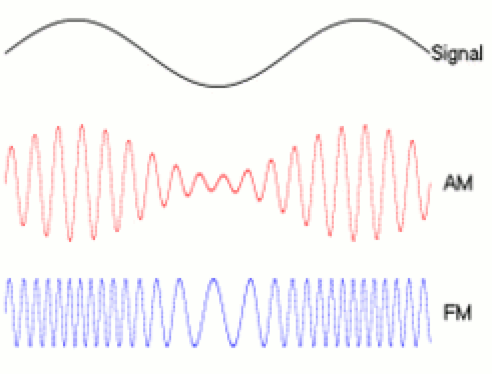
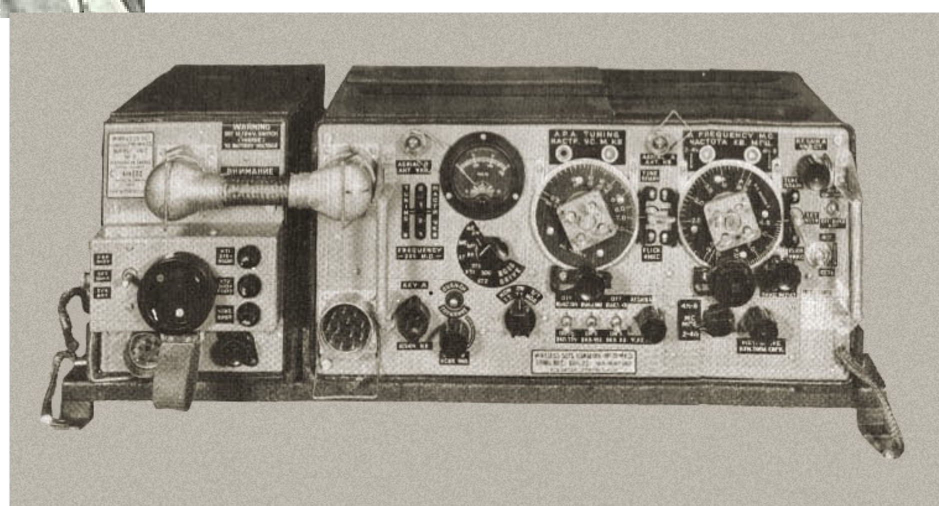
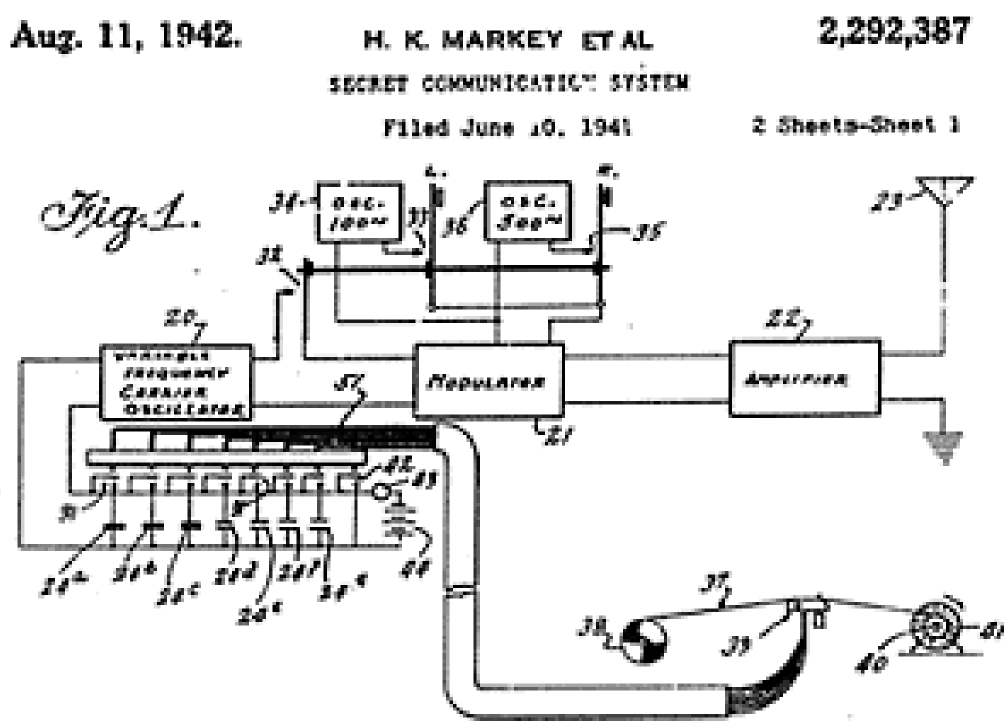
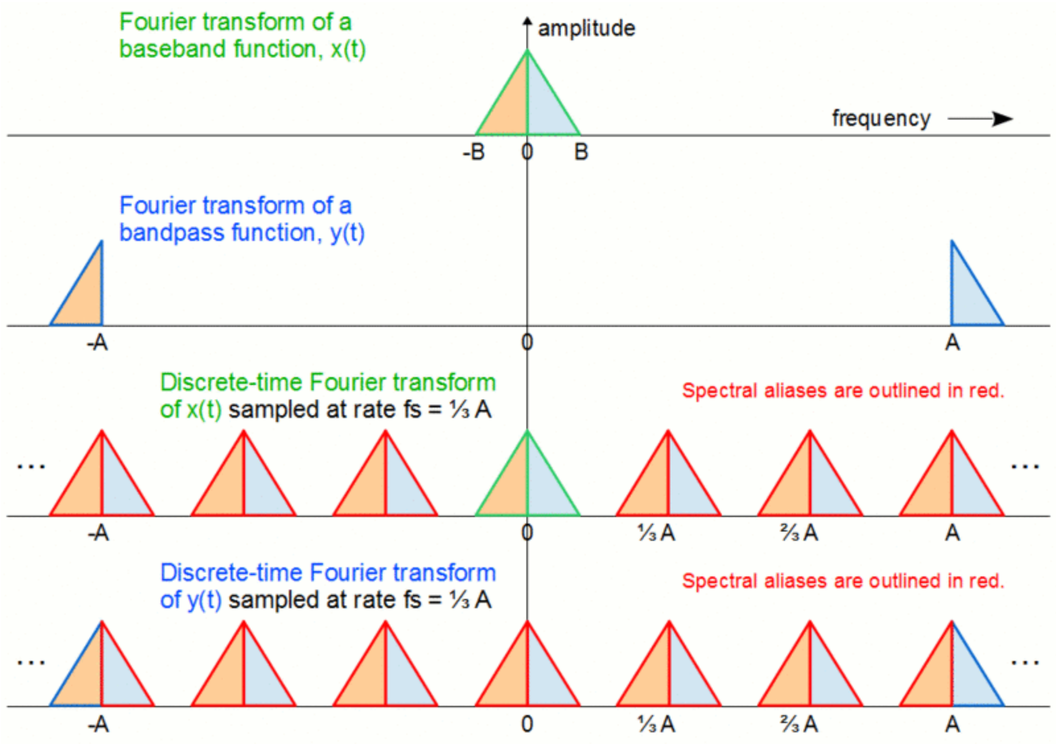
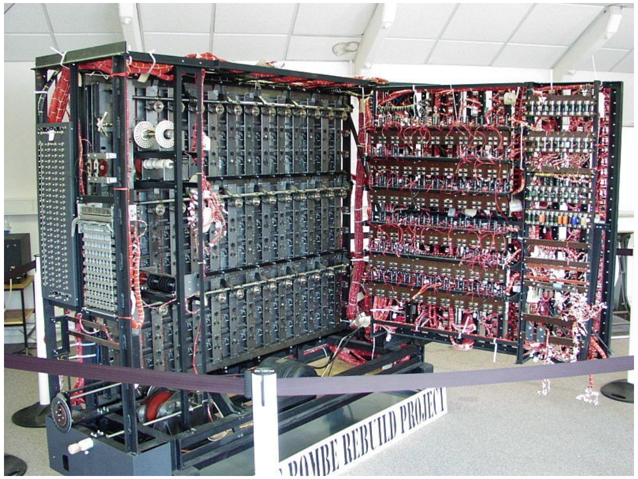

Signal
AM
FM

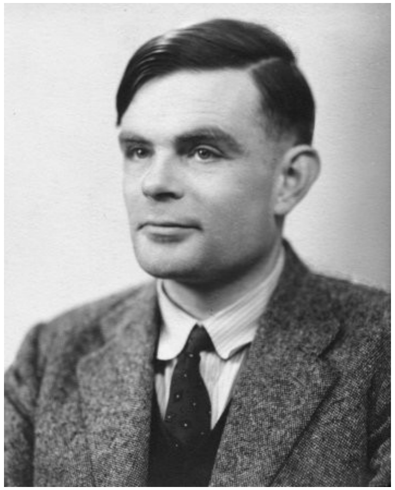
Figure 1. Radio Set SCR-300-A. In Use, Viewed From Right Side.

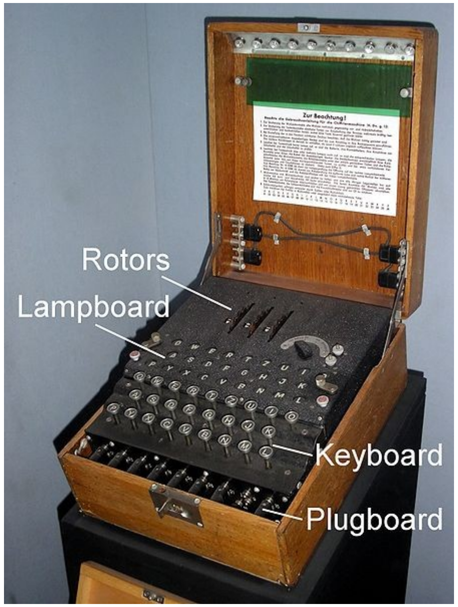



Aug. 11, 1942.
H. K. MARKEY ET AL
2,292,387
SECRET COMMUNICATION SYSTEM
Filed June 10, 1941
2 Sheets-Sheet 1
Fig.1.
OSC. 100~
OSC. 500~
MODULATOR
AMPLIFIER

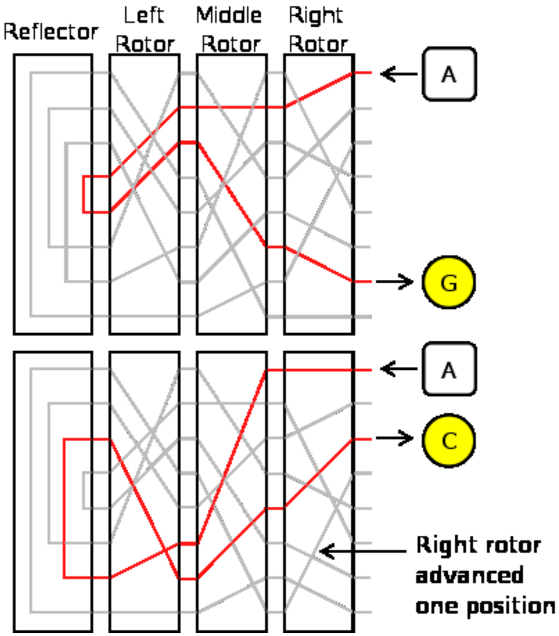

Fourier transform of a baseband function, x(t)
amplitude
frequency
-B
0
B
Fourier transform of a bandpass function, y(t)
-A
0
A
Discrete-time Fourier transform of x(t) sampled at rate fs = ⅓ A
Spectral aliases are outlined in red.
-A
0
⅓ A
⅔ A
A
Discrete-time Fourier transform of y(t) sampled at rate fs = ⅓ A
Spectral aliases are outlined in red.
-A
0
⅓ A
⅔ A
A



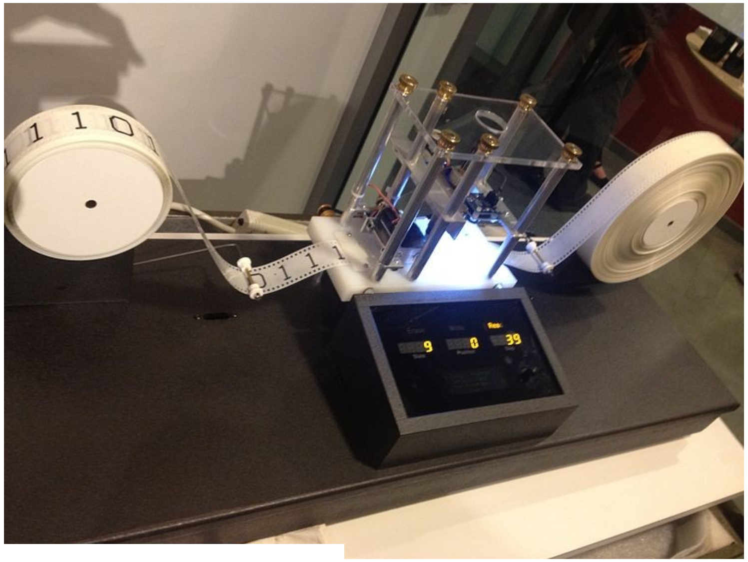


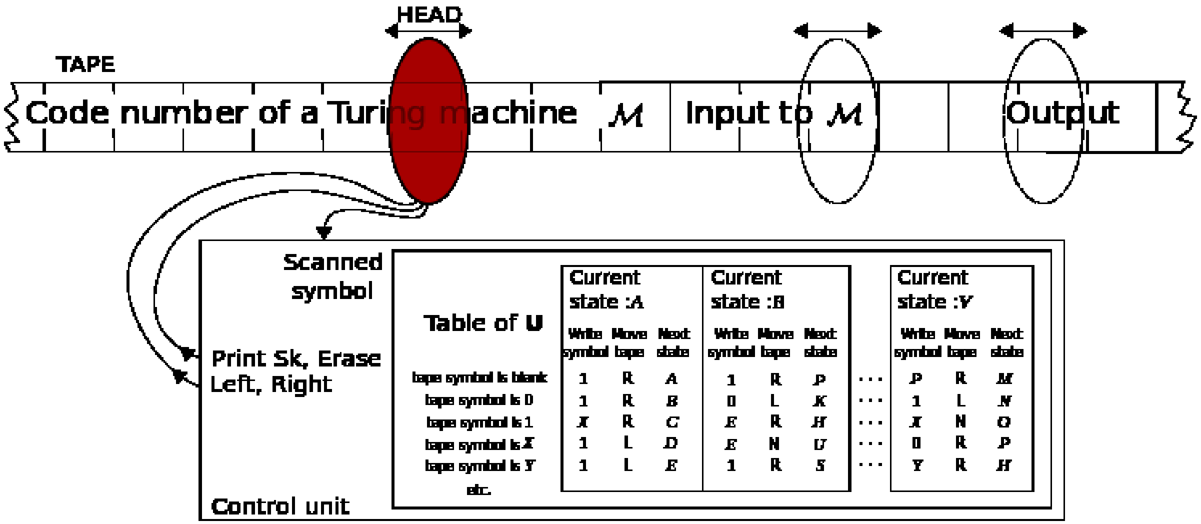


Rotors
Lampboard
Keyboard
Plugboard

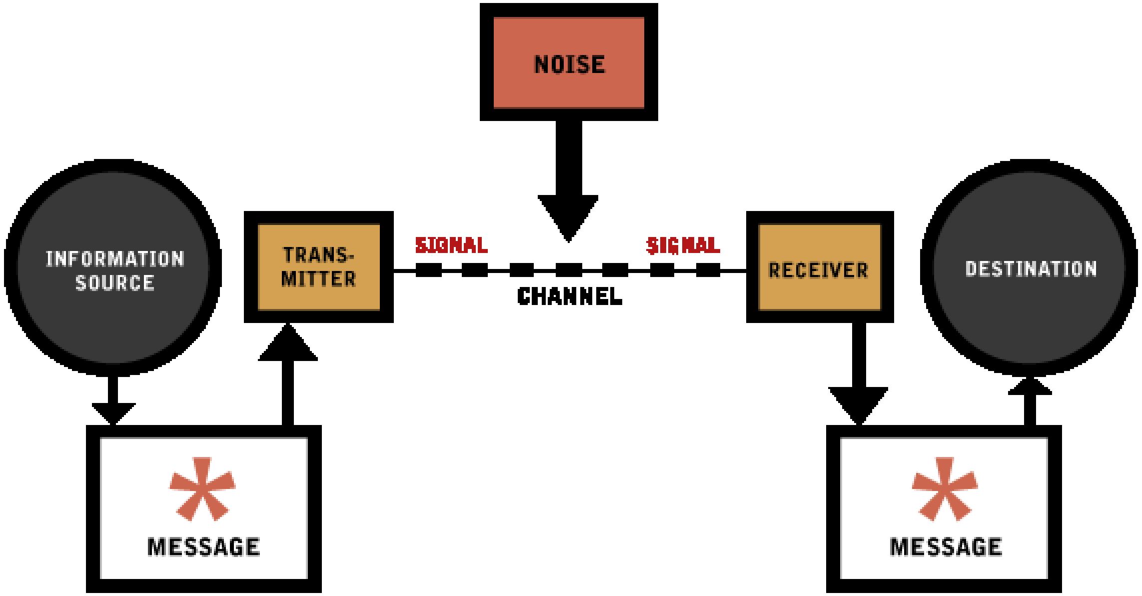


Reflector
Left Rotor
Middle Rotor
Right Rotor
A
G
A
C
Right rotor advanced one position




HEAD
TAPE
Code number of a Turing machine $\mathcal{M}$
Input to $\mathcal{M}$
Output
Scanned symbol
Print Sk, Erase Left, Right
Control unit
Table of U
Current state :A
Current state :B
Current state :Y
Write symbol Move tape Next state
tape symbol is blank 1 R A 1 R P P R M
tape symbol is 0 1 R B 0 L K 1 L N
tape symbol is 1 X R C E R H X N O
tape symbol is X 1 L D E N U 0 R P
tape symbol is Y 1 L E 1 R S Y R H
etc.

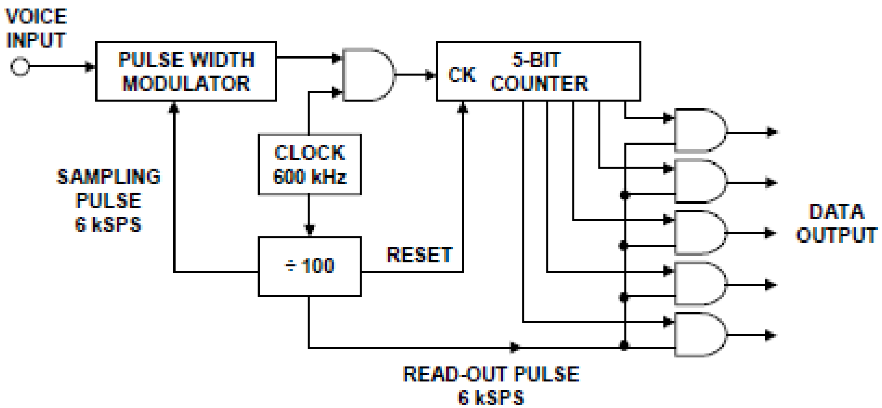
$$C = B\log_2\left(1+\frac{S}{N}\right)$$




2N3055
6-52

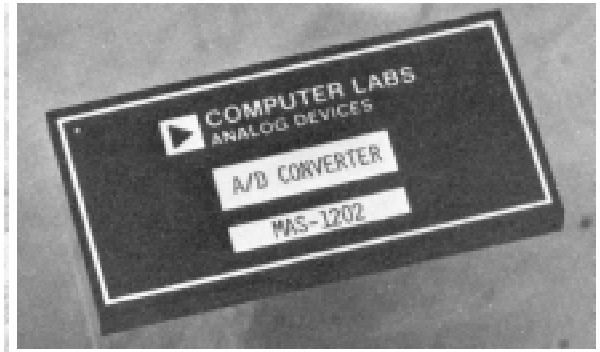

50 Years and Counting ...

Bundesarchiv, B 145 Bild-F077948-0006
Foto: Reineke, Engelbert | 8. April 1988



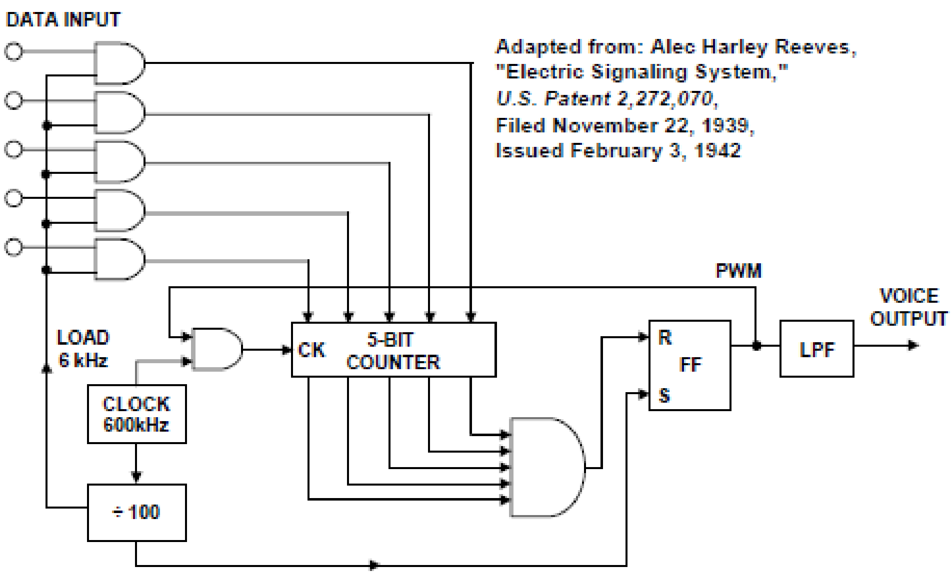
Adapted from: Alec Harley Reeves, "Electric Signaling System,"
U.S. Patent 2,272,070, Filed November 22, 1939, Issued February 3, 1942

MAS-1202 12-BIT, 2μs
SAR ADC INTRODUCED IN 1975



2" × 4" × 0.4", 2.4W, $270.00

Discrete PNP-Transistor Internal DAC, Manually Selected Precision Resistors



Adapted from: Alec Harley Reeves,
"Electric Signaling System,"
U.S. Patent 2,272,070,
Filed November 22, 1939,
Issued February 3, 1942

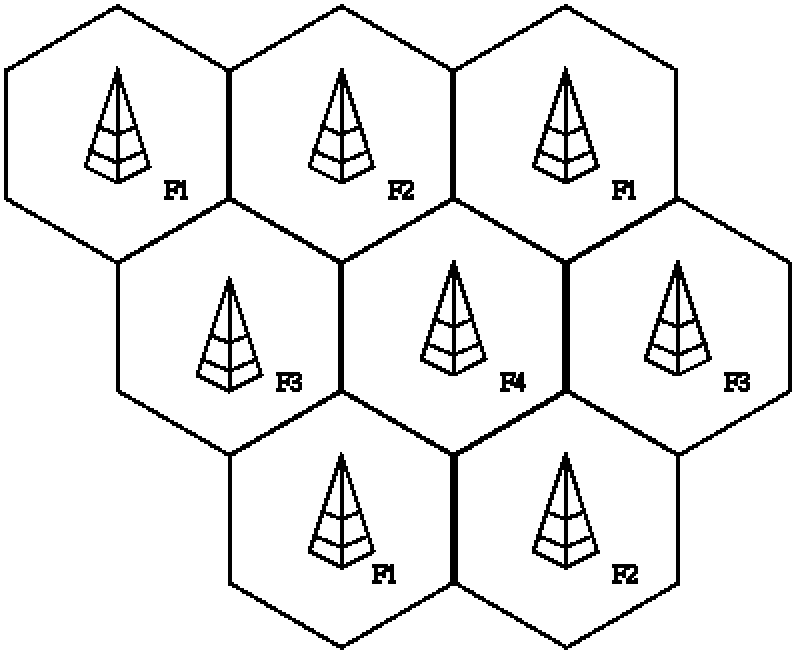
- 19" × 15" × 26"
- 500W
- 150 lbs
- $8,500.00

Courtesy,
Analogic Corporation
8 Centennial Drive
Peabody, MA 01960

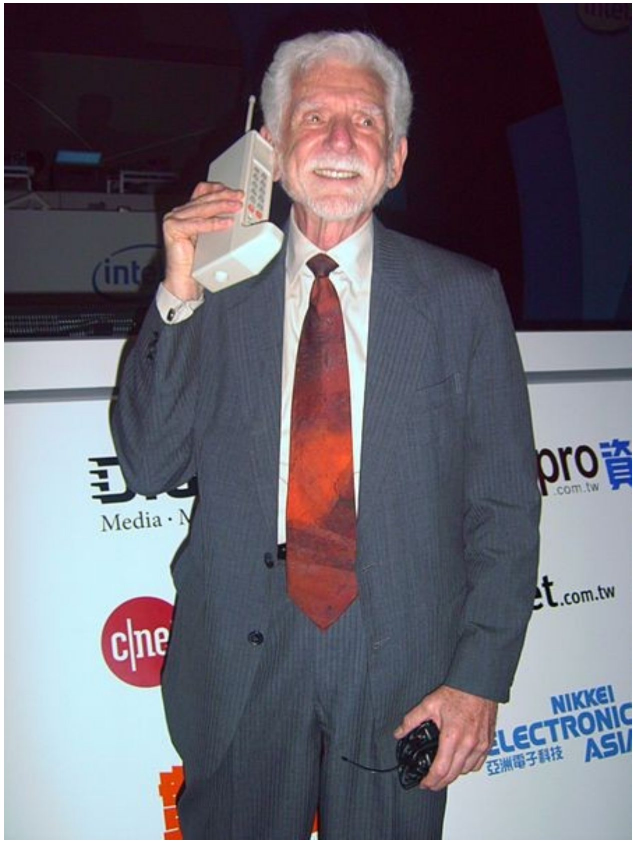
http://www.analogic.com

Figure 1.17: *1954 "DATRAC" 11-bit, 50-kSPS Vacuum Tube ADC Designed by Bernard M. Gordon at EPSCO*

AT&T
and Associated Companies


F1
F2
F1
F3
F4
F3
F1
F2

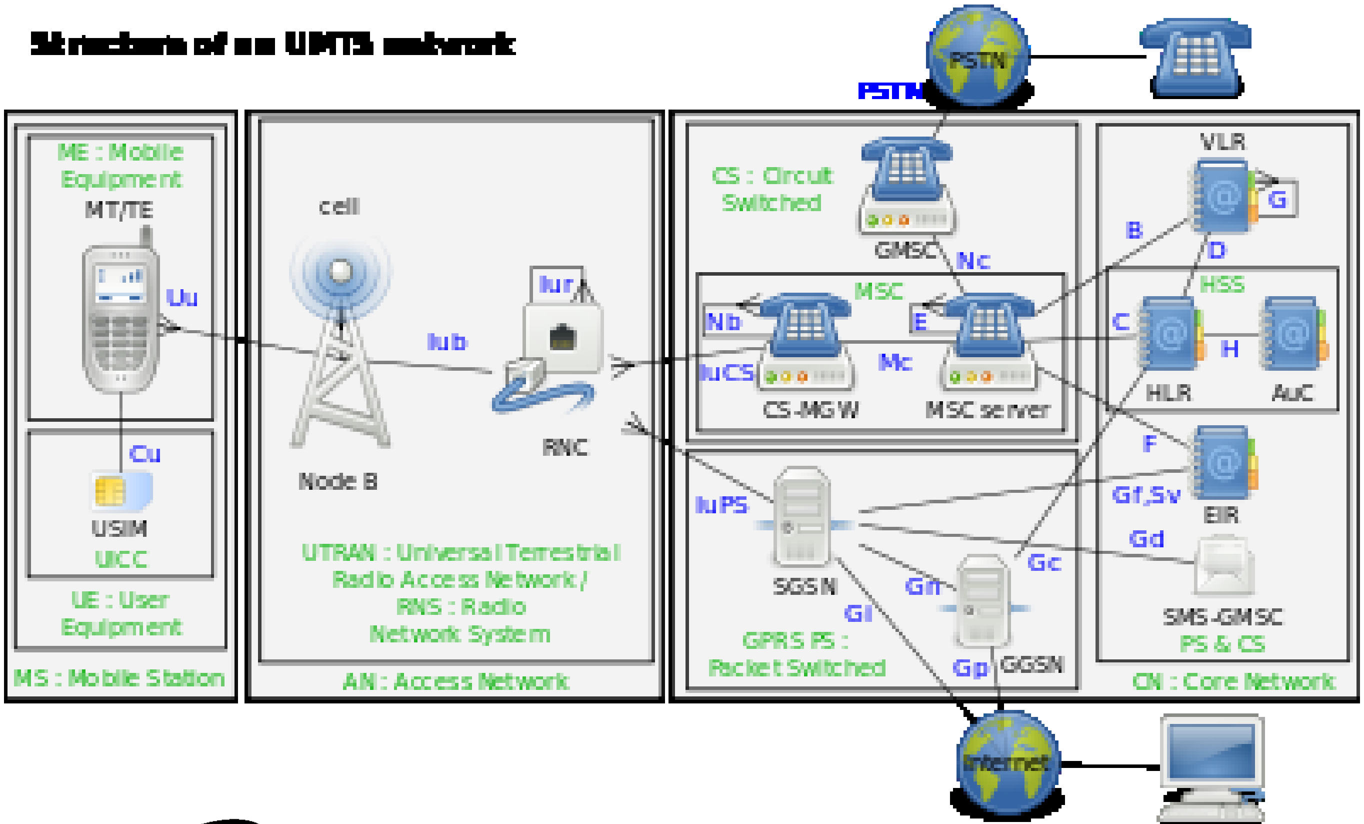

TELECOM


NIKKEI

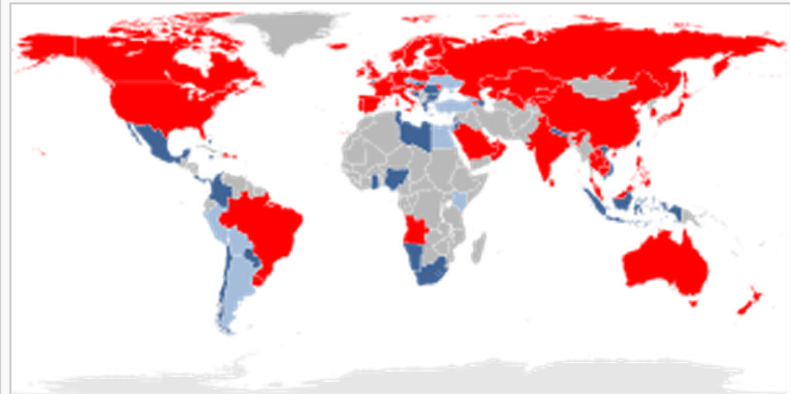
GSM™

SRS Software Radio Systems

CTVR the telecommunications research centre



A GLOBAL INITIATIVE



Adoption of LTE technology as of June 26, 2013.

Countries with commercial LTE service

Countries with commercial LTE network deployment on-going or planned

Countries with LTE trial systems (pre-commitment)

Thanks for your attention

Questions?