Background Data:
Military Communication and The Radio Game

Randy H. Katz
CS Division, EECS Dept.
University of California, Berkeley
Spring 2013

Quick History:
Electricity and Magnetism in the 19th Century

- Alessandro Volta (1745 - 1827)
  - Volt: the unit of electrical potential ("electromotive force")
  - Metals are "movers" of electricity: arrange metals in an electromotive series based on ability to gain or lose positive charges by contact
  - Voltaic pile: dissimilar metals separated by membranes moistened by acid -- the electric battery

E&M History

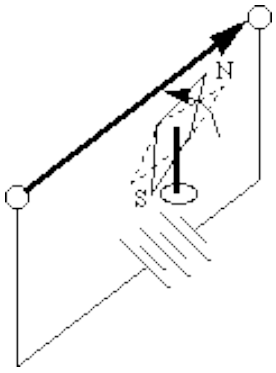
- Andre-Marie Ampere (1775 - 1836)
  - Amp: unit of electrical current ("velocity of electrical flow")
  - Demoed that magnetic effects between two current carrying wires are the same as those between a wire and magnet
  - Electrodynamics: mechanical forces between current-carrying conductors -- critical for the design of telegraph apparatus, telephone receivers, and loud speakers

E&M History

- Georg Simon Ohm (1789 - 1854)
  - Ohm: the unit of electrical resistance
  - Ohm's Law: I = V/R -- fundamental relationship between voltage (aka electromotive force), current, and resistance

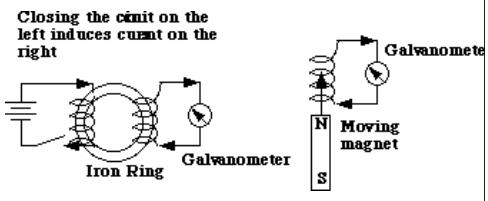
E&M History

- Hans Christian Oersted (1777 - 1851)
  - Forces of nature--light, electricity, magnetism, gravity--variations on one source. Magnetic field exists around a current carrying conductor. A deflecting force, such as magnetism, was something completely new. Connection between electricity and magnetism. Demonstrated this effect with the deflection of a magnetic compass needle.



E&M History

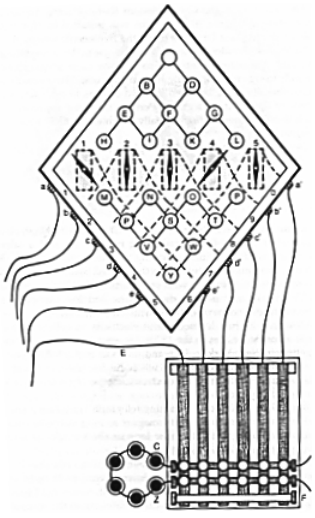
- **Michael Faraday (1791 - 1867)**
  - Farad: electrical unit of capacitance (stored electrical charge).
  - Built on Oersted: Demoed electric motor: wire carrying current rotated around a fixed electro-magnet. Wire rotates around magnet. Also showed how to make magnet rotate around wire.



Electrical Telegraph

- Telegraph — "Writing at a distance"
- Built on work of Volta, Faraday, Oersted. Signaling by means of electrical current along a conducting wire.
- Basic idea: deflect a needle by connecting and disconnecting a battery to a wire. By alternating the connection between the + and - poles of the battery, the deflection could be enhanced: needle reverses its swing.

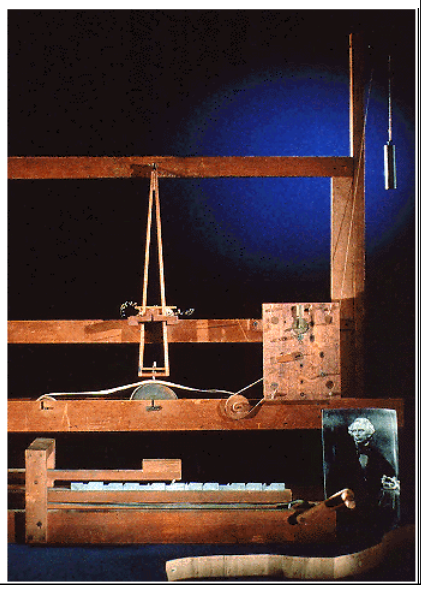
Wheatstone and Cooke



- 5 magnetic needles, deflected in pairs, selecting one of 20 letters of the alphabet. Original system required 5 wires. Later reduced to 2 by using coding techniques. 20 km of line installed along railway routes in 1838. Grows to 4000 miles by 1852.

Samuel F. B. Morse

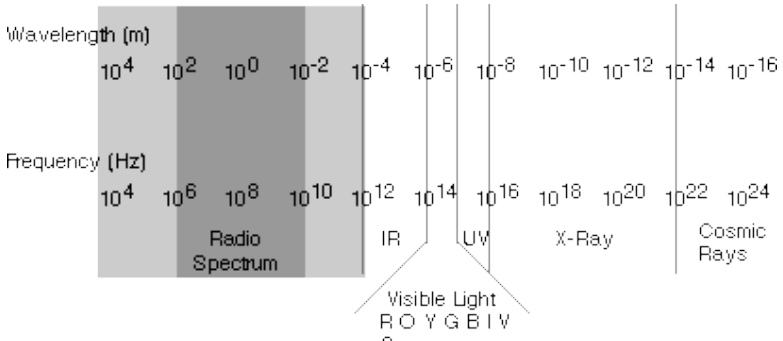
- 1835: "printing telegraph" -- key switches on current to electromagnet. Pencil makes mark as long as key is held down, drawing a long or short line on a moving strip of paper.
- 1837: Morse code – dots and dashes encode alphabet based on frequency of occurrence in English text



James Clerk Maxwell (1831-1879)

- Maxwell's equations described fundamental relationship between electricity, magnetism, wave propagation. Underlies all radio and cable communications. Light and radio waves are the same phenomena. Provides theoretical explanation for why radio waves can be focused and reflected just like light.

Electromagnetic Radiation



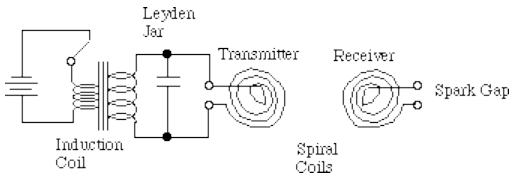
Speed of Light = $\lambda * f = 3 \times 10^8$

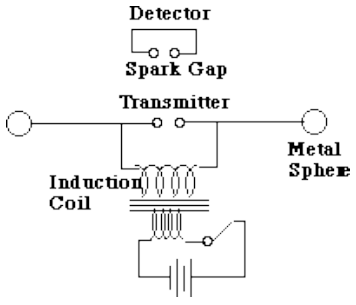
AM Radio	1 MHz	300 m	≈1000 ft
FM Radio, TV	100 MHz	3 m	≈10 ft
Cell Phone	1 GHz	30 cm	≈1 ft
Satellite	10 GHz	3 cm	≈1 in

< 30 KHz	VLF
30 - 300 KHz	LF
300 KHz - 3 MHz	MF
3 - 30 MHz	HF
30 - 300 MHz	VHF
300 MHz - 3 GHz	UHF
3 - 30 GHz	SHF
> 30 GHz	EHF

Electromagnetic Radiation

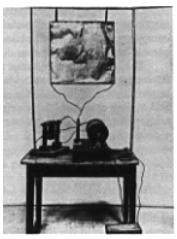
- **Heinrich Hertz (1857 - 1894)**
  - Hertz: unit of frequency: cycles per second.
  - Demoed experimentally wave character of electrical transmission in space. Developed apparatus that could transmit high frequency, meter length waves.

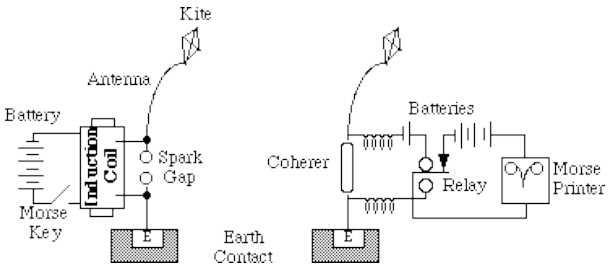




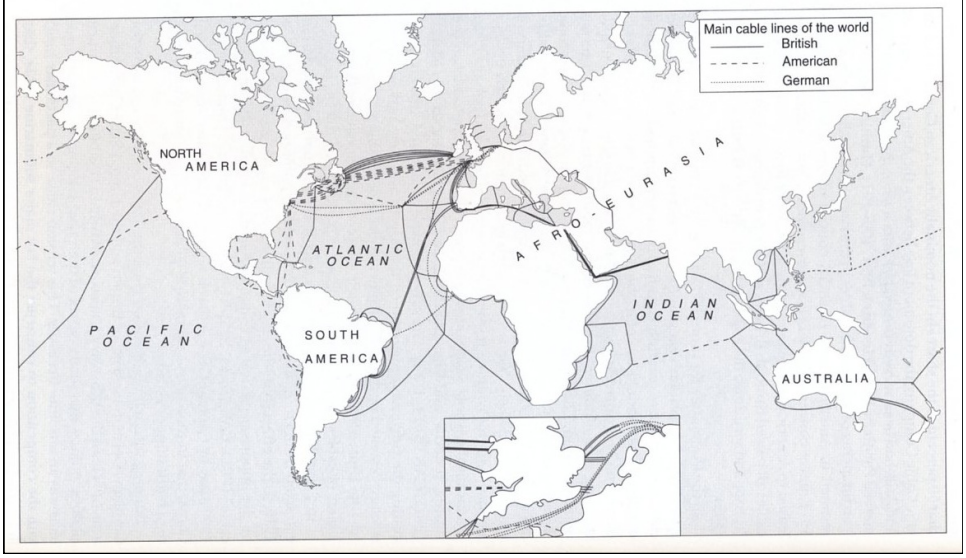
Radio Communications

- 1895: Guglielmo Marconi demoed electromagnetic radiation, created by spark gap, could be detected long distance.





Main Cable Lines -- 1911



Radio Communications in WWI

- Wireless plays key role!
  - Within hours of hostilities, British Navy cut Germany's overseas telegraphic cables; systematically attack German overseas radio stations and shut them down.
  - Germans similarly cut Britain's overland cables. … Marconi completes several radio stations under contract from the British government, to reestablish comms with overseas possessions. Techniques of communications intelligence (comint)—message interception, cryptoanalysis, direction finding, jamming, and intelligence gathering—developed rapidly.

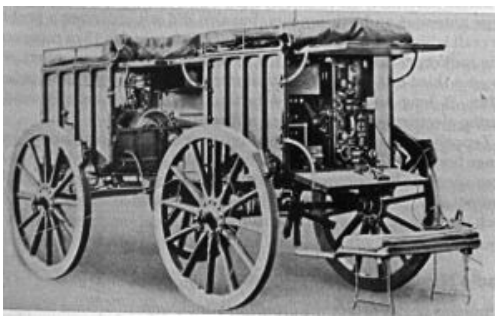
Airborne Radio Communications in WW I

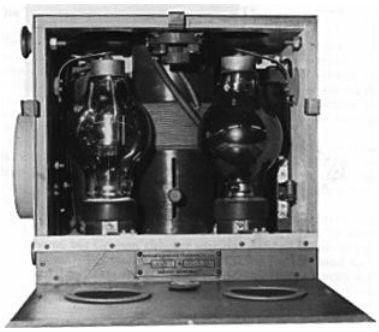
- "It became clear as we made our preparations … was not going to be anywhere near as simple as it had sounded. The first problem was the shear weight of the wireless apparatus. The guts of the system was a marvelously archaic contraption called a spark-generator. This worked by creating an arch through the teeth of a brass cog-wheel spinning against an electrode. Every time a tooth passed the electrode a spark jumped across the gap, and in this way, when connected to the aerial, it would produce a hideous, rasping crackle -- barbed wire made audible. The principle of signaling was that the operator worked a Morse key to turn this excruciating noise into a signal: a crackle for a dash and a short one for a dot."

Airborne Radio Communications in WW I

- "That part of the wireless alone weighed about thirty kilograms. But there were all the other accoutrements that went with it. Power was provided by a dynamo fixed on to a bracket under the aeroplane's nose and driven by a leather belt from a pulley-wheel on the propeller shaft: that weighed about seven kilograms. Then there was the aerial: twenty meters of wire with a lead weight at one end to trail behind us in flight, plus a cable reel to wind it in when not in use: about ten kilograms' worth in all. Other accessories comprised a signal amplifier, a tuning coil, an emergency battery, an ammeter, a set of signal rockets plus pistol and a repair kit. Altogether the wireless apparatus -- weighed about 110 kilograms. Or to put it another way, the weight of a very fat man as a third crew member."

Portable Radio, circa WW I





Radio Communications
WW II

- Command and control in "lightening warfare" (blitzkrieg)
  - Mechanized warfare demands leading from the front—radios in tanks let to quantitative edge
  - Rapid pace of operations does not allow for laying of wires—by-pass hard points to infiltrate behind the enemy
- Combined arms coordination
  - Bring to bear infantry, tanks, artillery, air power, even naval power
  - "Man" pack radios
  - Planes and ships don' t have wires

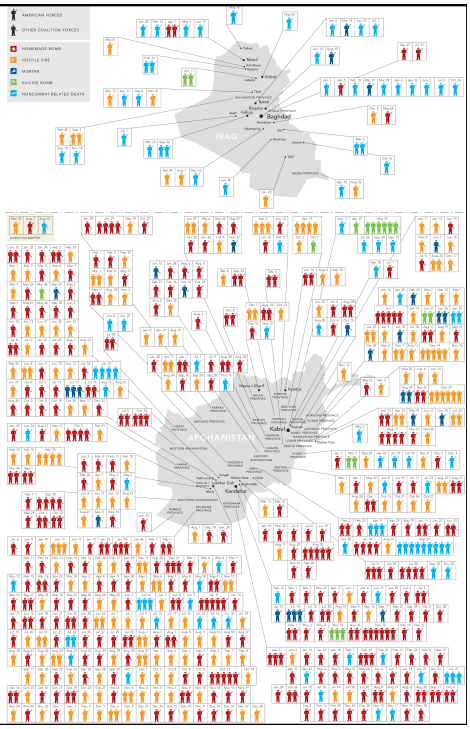
"A Bridge Too Far"

"A Bridge Too Far"

Afghanistan and Iraq Study

- See Class Web Page:
  - http://www.cs.berkeley.edu/~randy/Courses/CS39K.S13/insurgentessayreq.html
  - Due: 12 March 2013

US Fatalities in Iraq and Afghanistan in 2009



The Radio Game

- Two teams: Blue and Gold
  - Objective: be first team to collect the complete set of message segments and return with them to 310 Soda Hall
- Messages spread around Soda Hall and adjacent buildings
  - You must retrieve them in the correct order! Report to me your current message segment, and I will provide you with the location of the next segment

The Radio Game

- I tell you where the next message segment is located
- You go to that location, and tell me what the message says
- I then tell you the next location
- Repeat until done
- Winner is first to deliver ALL of the paper messages to me

The Radio Game

- You CANNOT steal the other team's messages!
- You CANNOT physically restrain or physically impede the progress of the other team in any way
- However, you can mess with their radio communications

The Radio Game

- Spend a few minutes as independent teams considering the following:
  - How do you choose a channel to begin?
  - What happens if the other team uses your channel? What is your strategy
  - Relaying: how to have team members spread throughout the building
  - Signaling protocol: what to do if you can't communicate with your team (signal may not reach)
  - What can you do to degrade the communications of the other team?

The Radio Game

- Discussion Questions:
  - Is hearing as good as seeing?
  - Is radio communications as good as face-to-face communications?
  - What is the effect of adversarial intermediaries in the middle of communications?

Background for Next Week

- Radar:
  - RAdio Detection And Ranging

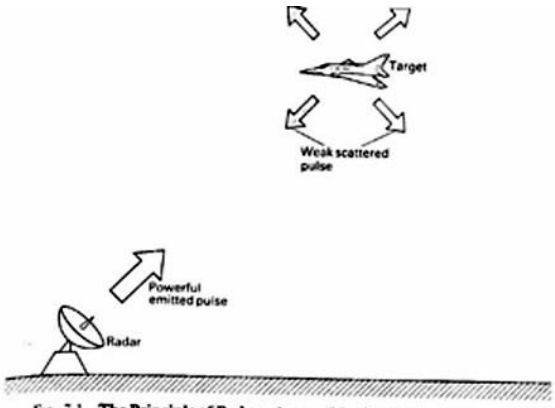


FIG. 7.1 **The Principle of Radar** A powerful pulse of radiation transmitted by the radar antenna induces electric currents in the target. These currents in turn radiate a pulse, but very much weaker, and scattered in all directions. Some of this scattered radiation returns to the radar antenna, which now functions as a receiving antenna. The time between the transmission and return of the pulse measures the target range. The return pulse is only detected when the radar is 'looking' at the target.

Background for Next Week

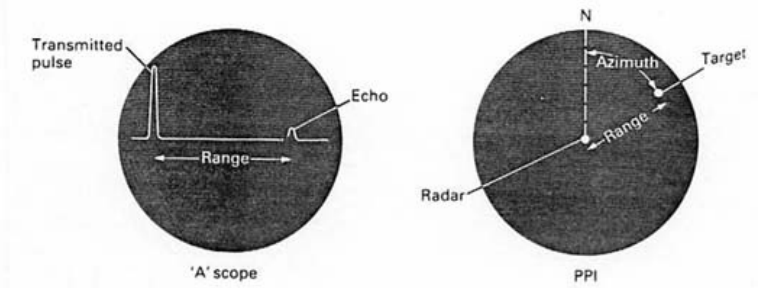


FIG. 7.2 **Forms of Radar Display** On the left above, the 'A' scope, with a baseline corresponding to a fixed time interval. The transmitted pulse registers at the left, the returned echo showing as a 'blip' at some distance to the right – the distance being proportional to the range to the target. On the right, the 'PPI' (plan position indicator), in which the radar is at the centre of the display, which shows not only distance but the direction of the target. In this illustration, North is assumed to be at the top.

Background for Next Week

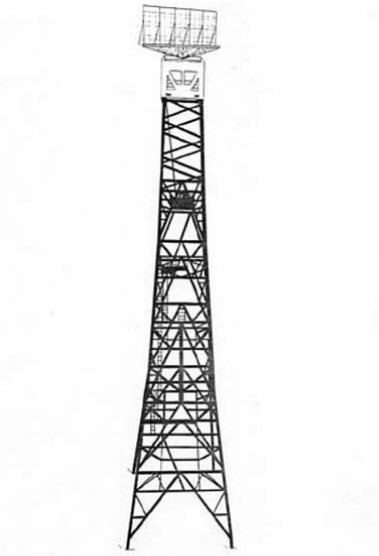


FIG. 8.1 **Chain Home Low** British radar technology leapt forward from Chain Home to Chain Home Low (CHL), which became the most numerous equipment during 1940. Working on the much higher frequency of 200 megahertz, it was compact and was mounted on rotating turntables to provide 360° scanning. It was mounted on 185-foot towers (as above) or cliff tops to improve performance against low-altitude intruders. Like Chain Home, CHL used horizontal polarisation, a good choice for long-range surveillance out to sea, but prone to ground clutter inland, and it remained chiefly a coastal radar. CHL was the first radar to make ground-controlled interception (GCI) possible at night.

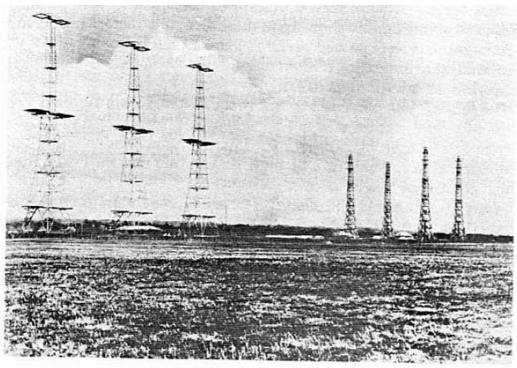


PLATE 7.1 **Chain Home** Chain Home provided the world's first strategic air defence radar network, erected along the east and south coasts of Britain (later extended to the west coast). It used High Frequency and consequently demanded large installations. 360-foot-high transmitter masts are seen on the left of the photograph above and 240-foot receiver masts on the right (*Photo: By courtesy of GEC-Marconi*)

Next Week: The Battle of Britain Game

- Fighters vs. Bombers
  - What are good targets?
    - Strategic vs. tactical plans
  - How do you intercept attackers?
    - Where is the enemy? Radar to observe planes at a distance
    - How to confuse the defender as to attacker's plans and intentions?
    - Getting the fighters to arrive at where you expect the bombers to be