Air and Space this Week

Item of the Week

Marconi and Fessenden

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Direct communications over a great distance has always been a goal for many reasons. From the watchtowers of the Anasazi at Chaco Canyon to naval flags ignored by Nelson to nuclear missile submarines at deep submergence to all of us with cell phones, we all use and value being able to communicate with whom we desire, at anywhere on the planet.

But it has only been that way for a little over a century. And a guy named Marconi, and another you probably never heard of, made it that way.

Electricity was still a novelty in the mid-1800’s, but we were beginning to understand it and how to use it. On the communications front, one of the key inventions was the electric telegraph by Samuel Morse, demonstrated first on May 24, 1844.

Princeton professor Joseph Henry (who later became the first Secretary of the Smithsonian Institution) had experimented with simple electrical circuits and batteries in the 1830’s, demonstrating that electricity could ring a bell when a switch was closed and other applications. Henry even published an article in which he suggested such a circuit could be used for communications (Morse was not familiar with this). Morse’s interest in practical electricity led him to CUNY professor Leonard Gale to discuss his ideas of sending a signal over a wire from point to point. Gale was a font of knowledge, and showed Morse how such a system could be set up to compensate for signal loss over long distances.

Two switches connected by wires with a battery in the circuit were all that was needed; the closing of one switch would cause the other to make a “click.” Morse quickly devised a code for click spacing, on still in use today. Wires were soon strung everywhere, allowing for rapid communication in code over long distances (much to the dismay of investors in the Pony Express!).

An Italian named Guglielmo Marconi was one of a number of scientists and technicians were working on the study and use of electricity. Marconi realized that the biggest drawback of telegraphy was the wire connection between communicators, and he dreamed of ways the need for them could be eliminated. He knew that there was a relationship between electricity, magnetism, and radiation created by changing currents, and he worked to see if that radiation might replace telegraph wires.

Marconi was inspired by the discovery of Heinrich Hertz in 1888 that long-wavelength radiation could be produced and detected. Working with the primitive electrical equipment of the day, Marconi succeeded in generating long-wavelength radiation that could induce a detectable current in a distant wire. Since all he needed was an "on, not on"-type signal, this was enough.

He developed a short-range system that he patented 1896, and formed the Wireless Telegraph and Signal Company in 1897. Improvements in his system increased its usable range that year, and by 1899 his company had established radio telegraph stations on either side of the English Channel. The following year he was able to demonstrate radio signal transmission over 2100 miles, a corner of the Atlantic.

One of the earliest lines of evidence that the Earth was round, not flat, was the appearance of a distant ship at sea. Sailors knew that only the tops of a distant ship could be seen, a condition they called "hull down," because the curve of the Earth blocked a direct view of the hull. In other words, the horizon blocked the view. Everyone initially thought that radio waves would be like light waves, and would only be good for line-of-sight. Not true. The wavelengths Marconi used seemed to follow the curvature of the Earth. We know now that those wavelengths are reflected the Heaviside Layer, ionized particles in the upper atmosphere.

Marconi quickly established a series of communications stations on both coasts of the USA and many other locations. He spent the first decade of the 1900's improving his system. One of its drawbacks was that a very long antenna (and a big power supply) were required for long-distance communications. Marconi's communications stations needed to be on or very near the coast, and have a lot of real estate for the antenna. One of the largest was set up in New Jersey, and a similar station was built near Bolinas, California; there were others, especially in the eastern US. More on them later.

In addition to trans-Atlantic and trans-continental communication, Marconi was also interested in ships at sea. They would have shorter range (due to antenna limitations), but could really use the system for both routine and emergency communication.

Marconi's system got a huge boost with the rescue of survivors from the *Titanic* sinking in 1912. The radio operators aboard the *Titanic* (who were Marconi employees) managed to get the word out, allowing rescue ships to arrive in time to save many survivors of the sinking. Nothing focuses public attention like the death of someone famous (John Jacob Astor, then one of the world's richest men, declined a life preserver or lifeboat spot and went down with the ship), or the flamboyance of a survivor (like the "Unsinkable" Molly Brown). Marconi and his system gained great fame and wide-spread recognition.

Marconi's wireless telegraph was a great step forward, with obvious important practical applications, but Morse code couldn't carry the same level of information voice communications does. [A telling note here is that Morse called his invention a "telegraph," literally a "distance writer," not a "telephone," literally a distance speaker."]

The next step up, voice communications, was made possible by the contributions of one Reginald Aubrey Fessenden, who recognized that one of the biggest limitations of Marconi's system was its power supply. He built a receiver of his own design, and worked with the US Weather Bureau under an interesting relationship (the USWS had an interest in the rapid transmission of weather data). A patent dispute eventually severed the relationship. Their loss.

Fessenden invented a better power source, a way to generate sine wave currents, and how to modulate the current strength – AM (amplitude modulation) radio! He patented a short-range system in 1901. He also figured out the basics of frequency-modulated radio (FM).

Alas, the brilliant Fessenden's business acumen did not match his engineering creativity.

Two venture capital guys created a company, NESCO, to finance Fessenden's work. His company scuffled along, charging prices too high for the Navy, and ignoring the potential of FM, radar, and sonar. An acquisition attempt by American Telephone and Telegraph fell through in 1906. The capitalists eventually fired him in 1911. NESCO then went into receivership, and was later acquired by Westinghouse (1920). Most of Fessenden's patents were sold to RCA in 1921.

After NESCO, Fessenden worked on marine communication, consulting with an outfit called the Submarine Signal Company. There he invented the Fessenden oscillator, an electro-mechanical transducer. SSC immediately applied the new invention to some uses, but they grossly-failed by overlooking its other potential, as basis for both radar (RAdio Detection And Ranging) and sonar (SOund Detection and Ranging)!

During WWI, Fessenden invented devices that would allow for the detection of enemy artillery and location of enemy submarines. He also invented a form of microfilm, and developed the basis for reflection seismology, which today is still one of the best items in the petroleum exploration geologist's toolboxes. Oh, and by the way, he received patents for tracer bullets, a television-type apparatus, and turbo-electric ship propulsion.

Marconi shared the Nobel Prize in Physics in 1906; Fessenden did receive a lot of professional recognition, but tell me, have you ever heard of him before?

Flash forward now to just after WWII. The long wavelengths required for skip off the Heaviside Layer could handle only slow data rates. A better relay system was needed. The one envisioned by (soon to be a famous science fiction writer) Arthur C. Clarke, and published in *Wireless World* magazine in 1945, called for a series of electronic signal relays to be placed in synchronous Earth orbit. A group of relay stations spaced around such an orbit would allow for rapid relay of radio, and television, information to anyplace on the globe with an adequate receiving station. Clarke's vision did not extend to the pace of coming advancements in electronics; in his model, the relay stations would have to be quite large in order to house the dozens of technicians required to monitor the relay station and change electric tubes when needed!

Reaching synchronous orbit was beyond the capability of early rockets. And the wavelengths needed to carry more information were line-of-sight only. One way of making them skip was to put up a reflector in the sky. The early satellites *Echo 1* and *Echo 2* demonstrated that the concept worked. They were giant orbiting balloons made of aluminized mylar, off which radio signals could be bounced over the horizon. It worked. However, the *Echo*s had very little mass, and a very big cross-sectional area, which made them exceptionally vulnerable to orbit decay. Rapid advances in both rocketry and in electronic miniaturization quickly made relaying the signals possible (see Telstar) rather than merely reflecting them, and also made possible placing such relays in geostationary orbits (see Syncom).

Prior to relay satellites, scientists even tried to use the Moon as a reflector-in-the-sky, both to bounce our signals off of, and to intercept signals of the other guy that came our way after inadvertently bouncing off the Moon. They actually succeeded in the former! As for the latter, well, let's just say that the Moon has an annoying habit of not being in a convenient position often….

The east coast Marconi station ….

The New Jersey Marconi site, Belmar Station, was taken over by the Navy in WWI. Its long-distance transmission capabilities were used for important operations, and for other purposes, such as propaganda and Armistice negotiations. Staff members were not only extremely capable operators of the communications gear, they were also innovators and experimenters; one such created a circuit less prone to static interference, which made a tangible difference under combat conditions.

After the War, the Navy turned the station over to its former staff, now reconstituted as an organization soon to become known as the Radio Corporation of America, RCA. Additional research was conducted at the site.

At some point, the Marconi facility became a hotel, and in 1925, the hotel and other buildings on the site were sold to the "Monmouth Pleasure Club," a group associated with the Ku Klux Klan. The hotel became the Klan's New Jersey headquarters. The Klan held a circus every summer, and planned to develop a community of 200 lots. Internal dissention and economic pressures of the Depression stopped those plans, and the property eventually went vacant. The Klan connection is rather ironic in the light of the events of next subsequent decade, when the Marconi facility again played an important role in military communication and research, an area in which African-Americans could, and did, make contributions not possible elsewhere in many corners of American society at the time. See: http://www.campevans.org/_CE/html/rj-nosc.html [The Bolinas Marconi facility also had its post-use life marred by undesirable association, at one point being the world headquarters for the Synanon cult.]

An abrupt about-face in usage of the Marconi facility came in 1936, when the site was purchased by the "Young Peoples Association for the Propagation of the Bible" organization. They founded King's College, a Christian school, still in existence in New York City (http://www.tkc.edu). The Marconi facility and grounds were too small for the growing school, forcing its relocation in early 1941. A timely change, because the U.S. Army needed the facility as a radio/radar research facility again! The Army renamed the facility "Camp Evans," after WWI Signal Corps officer LtCol Paul Wesley Evans (see: http://www.arlingtoncemetery.net/pwevans.htm). Camp history: http://www.campevans.org/_CE/html/history.html

Much of the WWII-era US research in radio direction finding, radar, and electronic countermeasures was conducted at Camp Evans. Advanced systems developed there, such as the SCR-584 integrated fire control and IFF radar system, when combined with the radio proximity fuse, decimated attacking aircraft and V-1 missiles.

Research continued after WWII, with Camp Evans being involved in the processing of captured German scientists (Operation Paperclip), testing spacecraft hardware, and hosting the ground stations for weather satellites *Tiros 1* and *2*, and more. Their involvement with spaceflight continued as long as the Army Signal Corps' did.

Camp Evans was closed in the early 1990's, but New Jersey did not want to lose the education/outreach value of the site, so the facility was occupied by an organization called **InfoAge**, who has also sought to provide institutional space for a variety of interesting exhibits; see: http://infoage.org/exhibits. ***NOTE: New Jersey recognized the value of this facility to STEM education; hey NASA (and Congress), you listening?***

The Camp Evans facility and the surrounding area was badly hit by Hurricane Sandy, ironic because it was an Evans-built instrument that returned from orbit the first Space-based image of a hurricane. Base power was not restored for some time (http://infoage.org/news-media/494-hurricane-pioneer-camp-evans-still-without-electricity-after-sandy-2013-06-09), with the former hotel facility used to house reconstruction volunteers (http://infoage.org/news-media/439-camp-evans-serves-as-base-for-sandy-recovery-groups-sng-2013-04-20). Initially, InfoAge managed to re-open on a short schedule, three part-days per week, using locally generated power. Part of the problem was funding for repairs, most of the problem was a fundamental incompatibility between Marconi- and modern-era electrical systems. It is now fully operational (apart from being closed now due to COVID-19); see: https://infoage.org and for abundant details on this facility, see: https://infoage.org/army-report-on-our-campus-history/.

… and Its Connection with Project Moon Bounce

On January 10, 1946, a modified version of Camp Evans' SCR-271 radar, a WWII air search system, was used to bounce radio signals off the Moon for the first time, a program called "Project Diana." Research in using the Moon as a reflector of military messages continued apace into the early 1950's.

The Moon was not an ideal radar reflector by any means (it lacks enough atmosphere to have a reflective ionosphere, as some had hoped), and efforts to pick up Soviet signals that just happen to bounce off the Moon were stymied by receivers not being adequately sensitive. But strong signals, aimed at the Moon, could be received with surprising ease. The first voice signal (Trexler speaking) was bounced off the Moon successfully on July 24, 1954 ("Operation Moon Bounce"), and military use continued through the 1950's.

The Moon Relay System was announced to the public in January, 1960. Showcased was a facsimile image of the aircraft carrier, *USS Hancock* (CV-19), with its officers and men spelling out "MOON RELAY" across her flight deck, transmitted from Honolulu to DC via a bounce off the Moon (see: http://history.nasa.gov/SP-4217.ch2.htm).

The Moon relay system worked, but had obvious disadvantages, not the least of which being that the Moon, at times, insists on being in an inconvenient location in the sky. Other passive reflectors were tested, such as *Echo 1* and *Echo 2*, giant aluminized gas bags. They worked, too, but they had enormous cross-section to mass ratios, making them extraordinarily vulnerable to even minute amounts of atmospheric drag. The lifetimes of low-mass orbiting reflectors were unacceptably short. Rapid progress followed, however, on putting actual relays (not mere reflectors) into orbit locations sited to minimize ground station infrastructure requirements (geosynchronous), and bouncing signals off the Moon for communications was no longer necessary.

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