

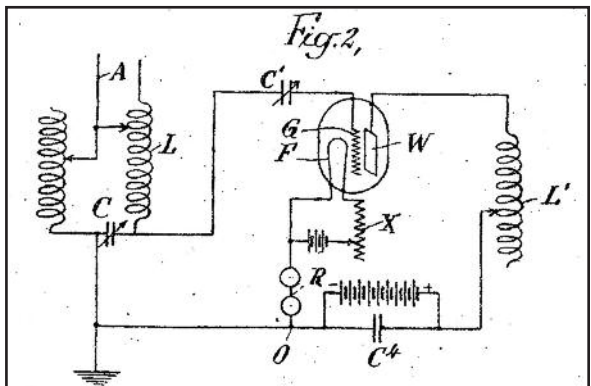
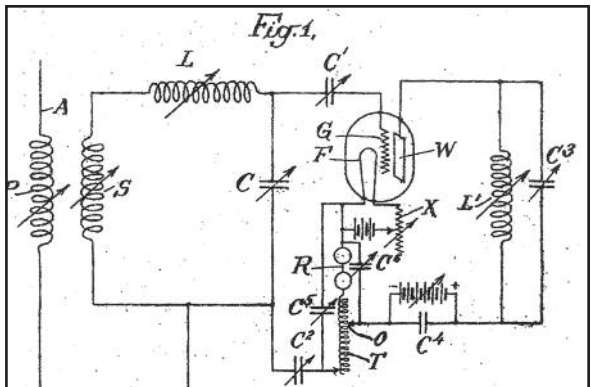
A PERSPECTIVE ON THE ARMSTRONG REGENERATIVE RECEIVER

In late summer 1912, roughly sixty years before Neil Armstrong stepped onto the moon, another man named Armstrong made an earlier “giant leap for mankind.” Edwin Armstrong was an engineering student at Columbia University and was also an amateur wireless telegrapher with strong interest in the burgeoning science of wireless technology. To appreciate the epic nature of his contribution, we should consider that Armstrong began his venture when wireless communication was in a very primitive state.

Wireless telegraphy in 1912 owed much to the practice of wired (land line) telegraphy that had been developed even earlier by Samuel F. B. Morse. Morse used an efficient code that permitted messages to be sent over telegraph wires as coded short and long pulses of electric current from batteries of electro-chemical cells¹. For wireless communication in 1912 however, amateur and commercial operators mostly used the electric spark gap to generate wave-like electro-magnetic (radiant) energy². In these earliest years, the generated energy wave-length was typically greater than 200 meters, corresponding to frequencies of 1500 kilohertz or

less. Wireless telegraphers interrupted this energy to form the characters of the Morse code.

For receiving the spark-gap-generated damped-wave energy³ and converting it to audible signals, operators used any of a variety of passive detectors, including the



Schematic drawings illustrating regenerative circuitry from Armstrong's 1914 patent

Fleming valve⁴. In a wireless receiving circuit this device functioned as a rectifier, and was used with a telephone ear piece⁵ to directly convert received spark gap energy to sound (acoustic energy in air).

Despite efforts to make the spark-gap signal more distinctive, its resemblance to natural background electro-magnetic energy (static) masked weaker spark-gap signals, and was therefore particularly unhelpful for long-distance communication. For reliable results with moderate transmitting power (1,000 watts), the distance covered using this equipment was typically less than a few hundred miles.

At this time, a device based on the Fleming valve was being offered by an experimenter-entrepreneur named Lee deForest. The device, that deForest named the "Audion," was a crude triode⁶ that functioned as a voltage-controlled regulator for electric current (as from electrochemical cells) and was finding use as an amplifier in wired telephone service. Apparently Armstrong was also experimenting with the Audion as an amplified detector for wireless signals.

On that eventful September evening in 1912, an inquiring Armstrong devised a novel feedback arrangement by coupling a controlled amount of energy from the Audion output circuit back to the tuned⁷ input of his amplified detector. With this tuned, circular, signal path, including the Audion's gain figure of about five, Armstrong might have briefly envisioned an infinity of multiplying gain cycles, although necessarily limited by the finite energy available in his electro-chemical cells. In fact, the resulting regeneration so greatly enhanced the performance of the detector⁸, that Armstrong heard spark stations at oceanic and continental distances.

With further adjustment of the feedback, Armstrong found he could produce a state of oscillation in the Audion circuit in which continuous-wave (CW) energy⁹ was produced at a wavelength determined by resonance in the tuning circuits. By arranging to couple this energy to an antenna, Armstrong created a transmitter for CW communication with most of the energy at a single fre-

quency. Compare this to spark gap transmitters that spread damped-wave energy over bandwidths measured in kilohertz.

Armstrong's regenerative feedback receiver next showed itself to be a superior detector of CW energy by virtue of its ability to oscillate, beating with the received CW signal to produce an audible tone. The tonal quality provided by the CW signal offered strong advantage over the noise-like spark gap signal. To further improve aural selectivity, it provided distinctly different tones for CW signals closely adjacent to the desired signal. This novel application of regenerative feedback to the wireless receiver and transmitter was surely an extraordinary intellectual and technological leap.

In the history of civilization, the appearance of the regenerative feedback transmitter and receiver must constitute a "eureka moment" and the true birth-event for immediate world-wide communication. After this time, a high-school student could put together this simple Armstrong equipment and, using the Morse code, could converse with another such person on the other side of the world¹⁰. Surely this astonishing capability defines the appeal of regenerative radio circuits and the place of Armstrong's regenerative receiver in the history of science and technology¹¹.

NOTES

1. The first useful source of continuous electric energy involved chemical reaction between dissimilar metals and an electrolyte, and was discovered in 1800 by Alessandro Volta. In 1836, John F. Daniell invented an electrically stronger and more durable form of electrochemical cell that became the electric current source for early telegraph systems.
2. Wave-like electro-magnetic radiation was predicted in 1865 in James Clerk Maxwell's renowned mathematical construction which was based on earlier work by Ampere and Faraday describing the magnetic field surrounding conductors carrying electric current. Elec-

- tro-magnetic radiation was first demonstrated in 1887 by Heinrich Hertz when he produced pulses of electric current in a conductor using a spark gap to discharge electric energy stored in Leyden jar capacitors. The resulting radiant energy was confirmed when simultaneous sparking occurred in a separate micro-gap detecting circuit.
3. Start-and-decay sinusoidal (signal frequency) waveform, repeating at sparking rate.
 4. The Fleming valve, produced by J. A. Fleming in 1904, was essentially an Edison Effect bulb that was designed specifically to be a detector for wireless receivers. As early as 1880, Thomas A. Edison had observed that an electric current could be made to flow from an incandescent wire filament to a separate metal plate when both were mounted in an evacuated glass bulb. Edison noticed that, for a current to flow, the filament must be charged negatively with respect to the plate; therefore, current could be made to flow only in one direction. This relationship became known as the Edison Effect.
 5. The telephone earpiece is part of the telephone apparatus invented by Alexander Graham Bell in 1876. The earpiece produces acoustic energy in air (sound) in response to a modulated electric current, and consists of an iron diaphragm that moves in reaction to magnetic flux from an electro-magnet that is energized by the modulated electric current. That current may be provided by, for example, the detector in a wireless receiver.
 6. The word "triode" refers to a third element that de Forest inserted between the filament and plate in the basic Fleming valve. The polarity and magnitude of charge difference between the new element and the filament was seen to control the magnitude of current flow between filament and plate.
 7. Beginning by about 1900, resonance in circuitry using discrete inductance and capacitance components provided wavelength/frequency selectivity for receivers and transmitters.
 8. The amplification (gain) that Armstrong experienced with feedback was possibly in the range of several thousand times the input signal level (see below: H. A. Robinson, etc.) Importantly, and perhaps unexpectedly, regeneration further acted to drastically improve the tuned detector's spectral selectivity; that is, to greatly narrow the received band-width to proportionally reject noise and interfering signal energy. This effect is known as "Q multiplication."
 9. Earlier short-lived efforts to produce continuous-wave (CW) energy include the Poulson Arc Transmitter, in which the electric arc current is controlled by a resonant electric circuit and the Fessenden Alternator, a rotary electro-mechanical generator of alternating current.
 10. The earliest recorded antipodal 2-way communication occurred in 1924 as amateur operators explored operation at shorter and shorter wave-lengths that incurred lower levels of atmospheric noise (static), and that favored "skip" propagation; that is, repeated signal refraction or reflection between earth and ionized layers of gas in the upper atmosphere.
 11. Not surprisingly, there is unresolved international conversation on this point. As might reasonably be expected, versions of the Audion were also being built, and oscillation in amplifying circuits was being discovered, in Europe at the time of Armstrong's success in America. However, despite later claims by Lee de Forest, Armstrong is firmly accepted in the U.S. as the inventor of the regenerative receiver.

RELATED READING

- De Soto, Clinton, *200 Meters & Down*, The American Radio Relay League.
- Robinson, H.A., "Regenerative Detectors," *QST*, Feb. 1933.
- Murphy, Michael J., "Meissner Regenerated," *The AWA Review*, Vol. 22, 2009.