

Foreword- Armstrong Publications.

by
H. H. Beverage

I had the pleasure of meeting Major Howard Armstrong for the first time in 1920. During the following years, it was my good fortune to be frequently associated with him, and to appreciate his clear understanding of obscure phenomena. He was, perhaps, one of the last inventors of the experimental school, following in the footsteps of Tesla, Marconi, **Round**, **Fessenden** and **Alexanderson**. He was a great admirer of Marconi, and their methods had much in common. It was Major Armstrong's approach to set up apparatus to try out an idea and proceed with measurements until he had a clear mental picture of exactly how and why he obtained the observed results.

Major Armstrong was the first to clearly point out how the De Forest audion worked and how it was possible to obtain enormous amplification by the heterodyne method. He expounded on the limitations of the vacuum tube amplifier at high frequencies and how these limitations could be overcome by his invention of the superheterodyne receiver. He discovered the phenomenon of the superregenerative circuit by accident and carried out extensive experiments with it until he understood just how it worked. I recall that he explained the operation of the superregenerative circuit to me on a special train taking a group of distinguished visitors to the opening ceremony at the Rocky Point transmitting station in 1921.

In the early 1930's, RCA Communications, Inc. was conducting experiments with the reception of frequency modulated telephony on high frequencies. The transmitter was

located at Bolinas, California, and the receiver was at Riverhead, Long Island, N.Y.. It was hoped that frequency modulation would be helpful in overcoming selective fading due to multipath transmission. Actually, frequency modulation was found to be inferior to amplitude modulation in the presence of multipath transmission as pointed out by Murray Crosby (Frequency Modulation Propagation Characteristics, Proc. IRE, June 1936).

Major Armstrong picked up these FM transmissions from Bolinas at his laboratory in New York. He came out to Riverhead frequently to compare results. At one time, Major Armstrong asked me what the limitation was in the reception of very high frequencies where multipath transmission was not a factor. I replied that the limitation was mostly due to tube hiss and cosmic noise. Some time later, he said that he believed that this limitation could be minimized by using frequency modulation with deviation greater than the modulation frequency, and that an improvement could thereby be obtained by widening the bandwidth of the receiver, contrary to the theoretical considerations held at that time. He indicated that the signal-to-noise ratio would improve in direct proportion to the FM deviation. I recall that shortly after Christmas, 1933, Major Armstrong came to my office in New York and handed me the original group of patents on wide-band FM which had just been issued, with the statement "this is the arrangement I have been telling you about".

Major Armstrong presented his classic paper on the wide-band FM system before the Institute of Radio Engineers in New York on November 5, 1935. Murray Crosby had worked out the theory of frequency and phase modulation, including wide-band frequency modulation. Crosby presented his paper

before the IRE in New York on January 8, 1936. In his comments and discussion of Crosby's paper, Major Armstrong stated that Crosby's results agreed pretty well with his own observations and measurements, but that inventions were not made by theoretical mathematics, but by 'jackassing' storage batteries around the laboratory. Professor Alan Hazeltine, President of the IRE at the time, disagreed with the Major, stating that "whatever little inventions that I may have been able to make were first worked out mathematically on paper and then reduced to practice in the laboratory".

This is perhaps an outstanding example of the difference between the experimental approach of Marconi and Armstrong versus the theoretical approach which is in wide use today. Three times, Marconi disregarded the theory that said "it can not be done" and proved by experiment that it could be done. The first time was in 1901, when Marconi transmitted the letter "S" from Poldhu, Cornwall, England to Newfoundland. The second time took place in 1924 when he reduced the wavelength of the Poldhu transmitter to 32 meters and surprised the World (probably including himself) by demonstrating that the 32 meter signals could be heard practically over the whole world in daylight, thereby opening up the high frequencies as an economical means of establishing world-wide radio communication. The third time was Marconi's experiments in the early 1930's wherein he demonstrated that the very high frequencies could be received up to over nine times the optical horizon, a phenomenon now known as tropospheric scatter. In like manner, Major Armstrong demonstrated the advantages of wide-band frequency modulation, contrary to the accepted theory at the time.

I was present at the IRE meeting in Philadelphia in 1934 when Major Armstrong attempted to give back the IRE Medal of Honor which he had received in 1918 for his invention of the regenerative circuit. Since the Courts had awarded this invention to De Forest after years of bitter litigation, Major Armstrong felt that he was not entitled to the Medal. C.M. Jansky, Jr., President of the IRE, called the Board of Directors into an emergency session to discuss Major Armstrong's decision. All members of the Board felt that the Courts had made a grievous error in awarding the invention of the regenerative circuit to De Forest and that it was clear that Armstrong was the real inventor. The Board reaffirmed that the Medal of Honor was properly awarded to Major Armstrong and refused to accept its return.

The role of the individual inventor is still as important as ever. However, the art has advanced to the point where it is generally impractical for a lone inventor to develop a basic invention into a commercial product. For example, the development of the transistor and the laser has required the services of hundreds of physicists, chemists, metallurgists and engineers to arrive at a commercial product.

The group of papers by Major Armstrong is a fitting monument to a truly great inventor, who, more than any other single inventor, laid the foundation for radio communication in all of its many forms.

April 13 1960

To: Messrs. E. V. Amy,
G. E. Burghard,
J. H. Bose,
H. W. Houck,
H. Sadenwater,
T. J. Styles.

Subject: Publication of all available papers of Edwin H. Armstrong,
by the Armstrong Memorial Research Foundation, Inc.,
as authorized by its Board of Directors.

Following is a list of papers presently available:

No. of pages

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| 29 | The Operating Features of the Audion - Annals of the N.Y. Academy of Sciences, Aug 2 1917 - Vol. LXVII, pps 215/43. (Article originally appeared, in part, in Electrical World Dec 12 1914, and, in part, in Proc. Inst. of Radio Engrs. Sept. 1915). |
| 33 | Some Recent Developments in the Audion Receiver. Proc. IRE, Sept. 1915, pps 215/47. |
| 16 | A Study of Heterodyne Amplification by the Electron Relay, Proc. IRE Vol. 5 No. 2 Apr. 1917, pps (cover) 145/159. |
| 3 | The Regenerative Circuit, Electric Journal, Vol. XIII No. 4, 1921. |
| 25 | A New System of Short Wave Amplification, Proc. IRE, Feb 1921, pps. 3/27 |
| 17 | Some Recent Developments of Regenerative Circuits, Proc. IRE, Vol. 10 No. 4 Aug 1922, pps 244/60 |
| 8 | The Story of the Super-Heterodyne - Its Origin, Development and Some Recent Improvements, Proc. Radio Club Am., Feb 1924; published by Radio Broadcast, July 1924. |
| 14 | The Super-Heterodyne - Its Origin, Development and Some Recent Improvements, Proc. IRE, Vol. 12 No. 5 Oct. 1924 pp 1/14 |
| 12 | Method of Reducing the Effect of Atmospheric Disturbances, Proc. IRE Vol 16 No. 1 Jan 1928, pps 1/12 |
| 52 | A Method of Reducing Disturbances in Radio Signaling by a System of Frequency Modulation, Proc. IRE Vol. 24 No. 5 May 1936 Vol. 24 No. 5 May 1936 pps 689/740 |
| 10 | Evolution of Frequency Modulation, Electrical Engineering, Dec 1940 (reprint) Cover and 9 pages |

No. of pages

- 9 Frequency Modulation and Its Future Uses,
Reprint: The Annals of The American Academy of
Political and Social Sciences Jan 1941, 9 pages
- 4 The New Radio Freedom,
Reprint: Journal of the Franklin Institute,
Vol 232 No.3 Sept.1941
- 4 Vagaries and Elusiveness of Invention,
Reprint: Electrical Engineering, April 1943
- 3 Nikola Tesla - An Appreciation
Reprint: Scientific Monthly, April 1943
- 25 The Original Disclosure of Frequency Modulation / ^{Broadcasting}
Revised (Reprint) of original 1936 paper which
appeared in Proc IRE, containing additional
material and comments by the author,
FM and Television, June, July and August 1944;
25 photostat pages (See also original issues)
- 3 High Points of FM History - FM & Television, Aug 1944,
pps 22/24
- 4 Mathematical Theory vs Physical Concept,
FM & Television, Aug 1944, pps 11/13, 36
- 18 A Study of the Operating Characteristics of the Ratio
Detector and Its Place in Radio History,
Proc Radio Club Am. Vol.25 No.3 1948, pps 3/20
- 6 Wrong Roads and Missed Chances- Some Ancient Radio
History,
Midwest Engineer, Vol.3 No.7 March 1951,
Cover and pps 3/5, 21, 25
- 7 The Spirit of Discovery, An Appreciation of the Work
of Marconi, (Reprint)
Electrical Engineering Aug 1953
- 11 Some Recent Developments in the Multiplexed Transmission
of Frequency Modulated Broadcast Signals (Reprint)
Proc. Radio Club Am. Oct 1953, pps 3/13
- 2 * Recollections of a Member of the Engineering Staff of
LBCG [Greenwich, Conn.]
-also-
- 5 * A factual account of Station LBCG - Prepared by
George E. Burghard with the collaboration of
Edwin H. Armstrong, read before Radio Club of
America Dec. 30, 1921

(*) Printed in Oct 1950 Commemorative Issue of
Proc Radio Club Am under title "The Story of the
First Trans-Atlantic Short Wave Message."

No. of pages

Total: 320

No copies of the following papers are presently available to Messrs. Burghard or Styles. If you can supply copies for publication your cooperation would be appreciated. List of unavallable papers follows:

A New Method of Receiving Weak Signals for Short Waves,
Proc. Radio Club Am., Dec 1919.

Theory of Tuned Circuits,
Proc. Radio Club Am., May/Dec 1913

Regenerative Circuit,
Proc. Radio Club Am., April 1915

The Super-Regenerative Circuit,
Proc. Radio Club Am., June 1922
Read before the Club June 28 1922 and reported in news form
in QST Aug 1922.

- T J Styles -

The Beverage (or "wave") antenna was invented in the early 1920s by Dr. Harold H. Beverage. It was first discussed in a paper titled "The Wave Antenna - A New Type of Highly Directive Antenna" written by Beverage, Chester W. Rice and Edward W. Kellogg for the journal of the American Institute of Electrical Engineers (Volume 42, 1923). The paper discusses testing longwave antennas (7,000 to 25,000 meters; 12-43 kHz) that were 7 miles (11 km) long. This work was done at Riverhead, Long Island, NY, and mentions "shortwave" tests around 450 meters (665 kHz) as a practical upper limit in subsequent experiments. While others have since written about the antenna, if you can find a reprint of this original work in a research library, you'll find the paper is fascinating reading.

In 1938, the Radio Institute of America presented Dr. Beverage with its Armstrong Medal for his work in the development of antenna systems. The Beverage antenna, the citation said, was "the precursor of wave antennas of all types." Dr. Harold Henry Beverage, Stony Brook, NY, USA, passed away on January 27, 1993 (at age 99).

Dr. Harold Henry "Bev" Beverage (14 Oct 1893 in North Haven, ME - 27 Jan 1993) is perhaps most widely known today for his invention and development of the wave antenna, which came to be known as the Beverage antenna and which for the last few decades has seen a resurgence in use within the amateur radio and broadcast DXing hobbyist communities. Less widely known (outside of the community of science history researchers) is that Bev was a pioneer of radio engineering and his engineering research paralleled the development of radio transmission technology throughout his professional career with significant contributions not only in the field of radio frequency antennas but also radio frequency propagation and systems engineering.

The **Beverage Antenna** is a relatively inexpensive but very effective long wire receiving antenna used by amateur radio, shortwave listening, and longwave radio DXers and military applications. Harold H. Beverage experimented with receiving antennas similar to the Beverage antenna in 1919 at the Otter Cliffs Naval Radio Station. By 1921, Beverage long wave receiving antennas up to nine miles (14 km) long had been installed at RCA's Riverhead, New York, Belfast, Maine, Belmar, New Jersey, and Chatham, Massachusetts receiver stations. The antenna was patented in 1921 and named for its inventor Harold H. Beverage. Perhaps the largest Beverage antenna -- an array of four phased Beverages three miles (5 km) long and two miles (3 km) wide -- was built by AT&T in Houlton, Maine for the first transatlantic telephone system opened in 1927.

While these antennas provide excellent directivity, a large amount of space is required. Beverage antennas are highly directional and physically far too large to be practically rotated so installations often use multiple antennas to provide a choice of azimuthal coverage.

A Beverage consists of a wire one or two wavelengths long (hundreds of feet at HF to several kilometres for longwave). A resistor connected to a ground rod terminates the end of the antenna pointed to the target area, a 470 ohm non-inductive resistor provides excellent results for most soils. A 50 or 75 ohm coaxial transmission connects the receiver to the opposite end of the antenna through an impedance-matching transformer. Some Beverage antennas use a two-wire design that allows reception in two directions from a single Beverage antenna. Other designs use sloped ends where the center of the antenna is six to eight feet high and both ends of the antenna gradually slope downwards towards the termination resistor and matching transformer.

Harold Beverage discovered in 1920 that an otherwise nearly bidirectional long wire antenna becomes unidirectional by placing it close to the lossy earth and by terminating one end of the wire with a non-inductive resistor with a resistance approximately matched to the surge impedance of the antenna. This was the fundamental discovery in his 1921 patent.

The Beverage Antenna relies on "wave tilt" for its directive properties. At low and medium frequencies, a vertically polarised radio frequency electromagnetic wave travelling close to the surface of the earth with finite ground conductivity sustains a loss that produces an electric field component parallel to the earth's surface. If a wire is placed close to the earth and approximately at a right angle to the wave front, the incident wave generates RF currents travelling along the wire, propagating from the near end of the wire to the far end of the wire. The RF currents travelling along the wire add in phase and amplitude throughout the length of the wire, producing maximum signal strength at the far end of the antenna where a receiver is typically connected. RF signals arriving from the receiver-end of the wire also increase in strength as they travel to end of the antenna terminated in a resistor, where most of the energy propagating in that direction is absorbed.

Radio waves propagate by the ionosphere at medium or high frequencies (MF or HF) typically arrive at the earth's surface with wave tilts of approximately 5 to 45 degrees. Ionospheric wave tilt allows the directivity inducing mechanism described above to produce excellent directivity in Beverage antennas operated at MF or HF.

While Beverage antennas have excellent directivity, because they are close to lossy earth they do not produce absolute gain (typically -20 to -10 dBi). This is rarely a problem, because the antenna is used at frequencies where there are high levels of atmospheric radio noise. The antenna has very low radiation resistance (less than one ohm) and will rarely be utilised for transmitting. The Beverage antenna is a popular receiving antenna because it offers excellent directivity over a broad bandwidth, albeit with relatively large size.

Directivity is a function of the length of the antenna. While directivity begins to develop at a length of only 0.25 wavelength, directivity becomes more significant at one wavelength and improves steadily until the antenna length reaches a length of about two wavelengths. Its generally accepted among Beverage antenna experts that directivity no longer improves when the antenna is longer than two wavelengths. Beverages longer than two wavelengths suffer from the phase incoherency of the incoming waves over distances of several wavelengths, resulting in phase incoherency of the currents induced in the antenna that degrades the directivity of the antenna.

The Beverage antenna is most frequently deployed as a single wire. A dual wire variant is sometimes utilised for rearward null steering or for bidirectional switching. The antenna can also be implemented as an array of two to 128 or more elements in broadside, endfire, and staggered configurations offering significantly improved directivity otherwise very difficult to attain at these frequencies. A four element broadside/staggered Beverage array was used by AT&T at their longwave telephone receiver site in Houlton, Maine. Very large phased Beverage arrays of 64 elements or more have been implemented for receiving antennas for Over-the-horizon radar systems.

A single wire Beverage Antenna is typically a single straight copper wire, between one and two wavelengths long, running parallel to the earth's surface from the receiver towards the direction of the desired signal. The wire is suspended by insulated supports approximately two meters above the ground. A 470 ohm non-inductive resistor is installed from the far end of the wire to a ground rod, although this value is not critical.

An impedance matching transformer (typically a 9:1 transformer to match the antenna to a 50 ohm transmission line) is used between the transmission line to the receiver and the antenna feedpoint. As an expediency, the transmission line can be connected directly to the end of the antenna and a ground rod usually with satisfactory results.

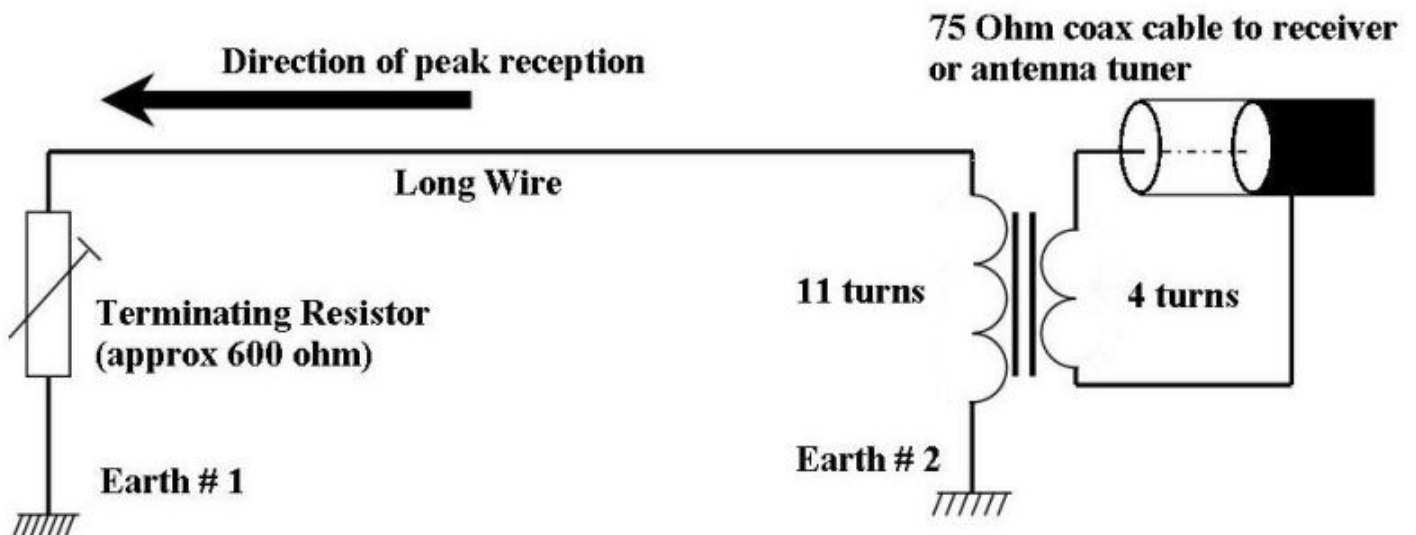


Figure 1: A basic uni-directional Beverage antenna