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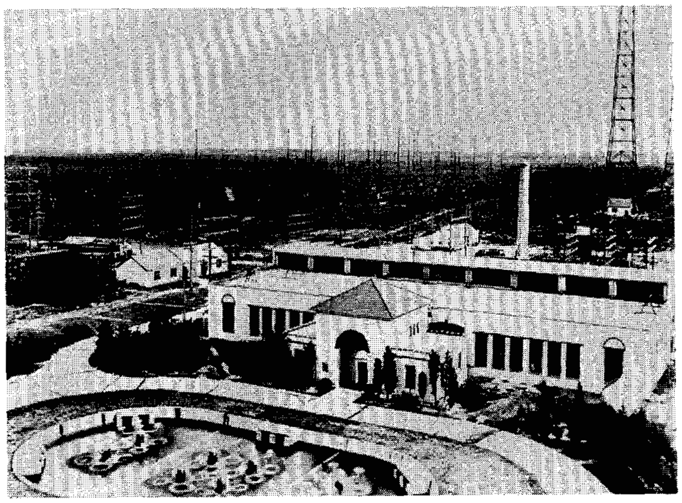
Some Notes on the History of Antenna Developments: 1913 through 1937



A panoramic view of the Rocky Point, Long Island Radio Transmitting Station of the RCA Communications in the early thirties.

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[It is my pleasure to share a portion of the early history of radio described by a true pioneer in the field of antennas, Dr. Harold Beverage. The AP-S owes Dr. Bondyopadhyay a debt of gratitude for his dedication and help in obtaining this contribution. WFC]

FOREWORD

Antenna research and development in the past hundred years since the epoch-making experiment of Heinrich Hertz, verifying the existence of electromagnetic waves, have advanced in distinct surges. The first surge, the Marconi era, spurred by Marconi's famous transatlantic wireless communication experiment in 19O1, saw the design, development and deployment of antennas for national and worldwide radio communication. This work spanned the long-wave region (10 kHz - 60 kHz) through the shortwaves (15 meters) , with the discovery of ionospheric reflection and the pivotal role it played in shortwave propagation and reception - through the twenties.

The leader of antenna research and development in the Marconi area, besides Marconi himself, is undoubtedly Harold Henry Beverage, pioneer in the establishment of national and worldwide radio communication. In the following memoir, he gives us a rare glimpse of the pioneering days with interesting anecdotes. Some of the antennas he invented have operated in the heart of Long Island to the service of this nation and the world. The Long Island/Mew York Chapter of the IEEE AP-S is justifiably proud of his pioneering contribution to the progress of mankind.

Probir K. Bondyopadhyay
Chairman, Long Island/New York Joint Chapter
IEEE Antennas and Propagation Society

SOME NOTES ON THE HISTORY OF

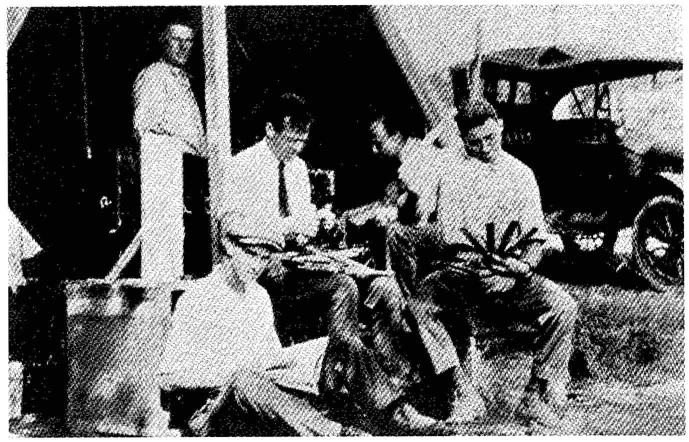
ANTENNA DEVELOPMENTS 1913 THROUGH 1937

When one arrives at the age of 95, he can recall events that happened 80 years ago, but has trouble remembering something that happened last year. It is difficult for me to establish dates, since the only reference book at hand is *History of Radio to 1926* by Gleason L. Archer. I can list some information concerning the development of antennas since I knew many of the people working on antennas, and I can only list general dates.

In 1914, Prof. Zenneck was constructing a long-wave station at Sayville, on Long Island, New York. It was a flat-top arrangement supported by several towers. It was similar to the antenna at Nauen, Germany, and was being constructed for commercial service with Germany. At the same time, another German engineer, named Emil Meyer, was constructing an antenna for French interests at Tuckerton, New Jersey. This antenna was supported by a tower about 800 feet high, standing on an enormous porcelain insulator. The antenna wires spread out like the ribs of an umbrella. The antenna cables also served as guys for the tower. After the war, I met Emil Meyer. He told me that when the United States declared war on Germany, he was arrested as a prisoner of war, and was placed on a train at Philadelphia bound for North Carolina. He was very upset until he saw that his friend, Prof. Zenneck, was also a prisoner of war on the same train. They were confined to a comfortable cottage in North Carolina. They were treated with respect, and were supplied with any books or other items that they needed. Emil Meyer qualified for his Ph.D. under Prof. Zenneck while they were prisoners of war. Prof. Zenneck wrote a book about wireless developments up to 1908. It is the "Bible" for that time. It still contains much information of use.

At approximately the same time that the Germans were building transmitting stations at Sayville and Tuckerton, the Marconi company was constructing stations at New Brunswick, New Jersey; Bolinas, California; Marion, Massachusetts; and at Kuhuka, Hawaii. Receiving stations were constructed at Belmar, New Jersey; Marshalls, California; Chatham, Massachusetts; and at Koko Head, Hawaii. The Marconi transmitting antennas were about a mile long, supported by triatics strung between two rows of six 400-foot-high tubular guyed towers. During the winter of 1918, the General Electric Company installed a 200 kilowatt Alexanderson alternator at New Brunswick. Downleads were brought down from the antenna at each of the six

The first RCA Antenna Laboratory at Wildwood Lake, Riverhead, Long Island, in the winter of 1919-1920. Dr. Beverage and P. S. Carter (one of the founding members of the IRE Antennas and Propagation Society) spent some cold days here in the tent working on the Beverage Antenna.

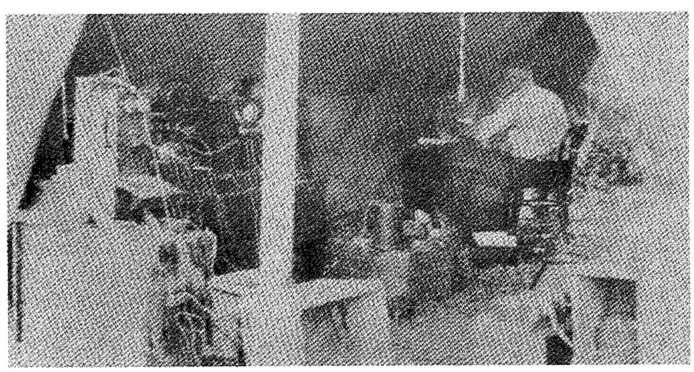


Harold Beverage conducting experiments on the "wave antenna" in the spring of 1920 at Riverhead, Long Island. From left: Beverage (standing), Mr. Olsen of the American Marconi Co. (seated in foreground), Chester Rice, Edward W. Kellogg, and Mr. Greenman (seated).

towers and extended through a tuning coil to ground. This reduced the ground losses six-fold, so 200 kW with a multi-tuned antenna was equivalent to 1200 kW with the original, single-tuned antenna. This made New Brunswick the strongest transmitting station in the United States (call: NFF), so it was taken over by the Navy for communication between Washington and the American forces in France.

In the early days, we referred to "wavelength" rather than to "frequency". The wavelength of WII, New Brunswick, New Jersey, was approximately 12,600 meters, or 23.81 kHz. The lowest frequency ever used was in a French station at Rio de Janiero, at 30,000 meters or 10 kHz. The most powerful station, to my knowledge, was a 1000 kW Poulson-arc station at Lyon, France, call letters "LY". The frequency was about 14.5 kHz. I could hear this station with the phones connected between the wave antenna and ground - no amplifier or tuned circuit. This was very interesting to Major Edwin Howard Armstrong.

In 1916, I was able to convince Dr. E. F. W. Alexanderson, inventor of the famous Alexanderson alternator transmitting system, that he needed someone on his staff versed in radio propagation and receiving system development. My first major assignment was to develop the Alexanderson Barrage Receiver system, an arrangement for directive reception. It was feared that the Germans might cut the transatlantic cables and "jam" the reception of American radio stations in France, thereby preventing communication between Washington and the expedition force in France. The barrage receiver, to be erected in France, would balance out any interference from transmitters in Germany. In addition, the French communication liaison officer, Lt. Patanoe, wanted an arrangement which would prevent the Germans from copying the American stations, a sort of "radio barrage". The antennas for the barrage receivers were insulated wires lying on the ground, extending two miles in opposite directions from the receiver. The first Barrage receiver was erected about four miles north of NFF, the powerful transmitting station at New Brunswick, New Jersey, using 200 kW Alexanderson alternators. This station was the main station used by the Navy for communication with France. The ground antennas extended two miles northeast and two miles southwest from the receiver, which was installed in an old farm house. The extremely strong signals from New Brunswick were readily balanced out while receiving weak signals from MUU in England at nearly the same wavelength. It was also found that the Barrage receiver also balanced out most of the atmospheric static arriving from the South. This feature interested the Navy, so they asked that a Barrage receiver be erected at Otter Cliffs, their main receiving station near Bar Harbour, Maine. I installed this system in the summer of 1918. The NE wire extended two miles from Otter Cliffs to Bubble mountain. The SW wire extended two miles to Hunters Beach, but crossed Otter creek on the bridge. It was found that the signals from Europe were excellent on the NE wire, but nothing but static on the SW wire. I thought that perhaps the reception on the SW wire was poor on account of the "dog leg" routing to cross the creek on the bridge, so I extended the SW wire from a tower to a high tree on the opposite side of the Creek, in order to clear the masts of the fishing boats which used the creek. There was no improvement. Finally, I "horsed" a receiver and storage battery



Harold Beverage with the Barrage Receiver (inside the tent) in the spring of 1920.

down the cliff at Hunters Beach. To my astonishment, the signals on the SW wire were excellent, just like the NE wire at Otter Cliffs. The wire was unidirectional, that is, it received signals from the direction in which it was pointed. But why? To find out, I and Philip Carter laid out a wire six miles along an old sand road extending SW from Riverhead on Long Island, New York. By cutting the wire and inserting a receiver at intervals, we determined how the European signals increased, while the static from the SW decreased, as we progressed southwest along the wire. We found that the losses in the wire lying on the ground were so high that the static reflected from the NE end of the wire never reached the receiver at the SW end of the wire.

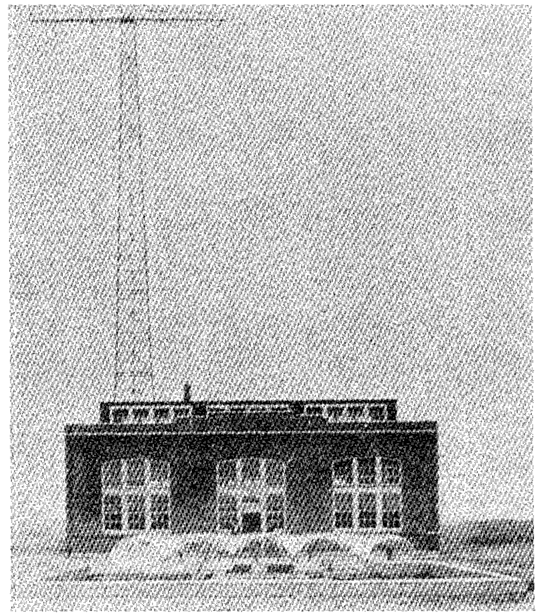
The obvious answer was to erect the antenna on poles to increase the velocity and decrease the attenuation. To prevent the static from being reflected from the NE end to the receiver at the SW end, a resistor equal to the "characteristic" resistance of the antenna would absorb the static and make the antenna appear infinitely long. A full-scale antenna on poles was constructed by the Long Island Lighting Company, extending nine miles from Riverhead to East Moriches. This was the first uni-directional aperiodic antenna. For the first time, it was possible to receive a wide band of frequencies, without adjustments to balance out the static and interference from stations south of Riverhead. For many years, all signals on long waves from Europe were received on this antenna, and the signals were sent to the message center at 66 Broad Street in New York, over wire lines provided by the telephone company. Actually, the nine-mile long-(14.484 kilometers) wave antenna at Riverhead was successfully used over the range of 5,000 meters, for reception from Germany, to 30,000 meters, for reception from the French station in Brazil.

In 1919, the General Electric Company installed a radiophone on the USS George Washington, for use by President Wilson on his return from Paris, to enable him to talk to Navy Secretary Daniels while the ship was at sea. John Payne installed and operated the transmitter; I installed the receiver and some of the radio equipment. I made many test calls from mid-ocean to the Navy Department in Washington. I was impressed by the excellent speaking voice of one person in Washington, so one day I asked, "To whom am I speaking?" The reply was, "This is the Assistant Secretary of the Navy, Franklin Delano Roosevelt." The USS George Washington made two trips to Brest, France. One day as I was dashing around the deck to meet a schedule with New Brunswick, I rounded a corner and almost ran into the President. I apologized most humbly, but the President did not appear to notice this humble person.

On July 4, 1919, the USS George Washington was in mid-ocean. The Navy station at Otter Cliffs, near Bar Harbor, Maine, was receiving signals from our radiophone. We heard that President Wilson was to address the troops, so we notified some 40 ships in the range to listen to the address. The troops were located on the open forward C deck. We asked the Captain of the USS George Washington, Captain McCally, as I recall it, where the President would stand. He suggested a spot on the B deck, overlooking the C deck, so we placed the microphone there. The President was unapproachable, so neither the Captain nor Admiral Grayson were able to tell the President about the position of the microphone. Accordingly, the President went down to the troops on C deck, about 25 feet from the microphone, so we could not modulate it. Some wag wrote an article about this entitled, "The voice that failed." After the President finished his address, we read it over the transmitter. Later we learned that it was heard as far away as Texas. I hope that at least God was able to hear this historic broadcast!

President Wilson thought that through his efforts at the League of Nations, there would never be another war between great nations. History records that the U.S. Congress did not approve the League of Nations charter. President Wilson practically collapsed physically and mentally.

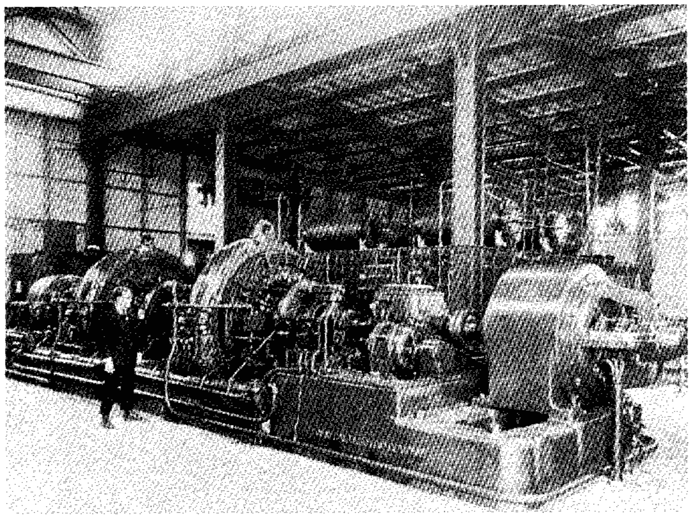
In November, 1921, I sailed on the SS Aquitania, bound for London to discuss details of an expedition to Brazil with Mr. Marconi and others. Paul Godley was aboard, bound for Scotland to listen for American amateur stations ("Ham" operators) on 200 meters. Naturally, he asked about the "wave" antenna, so I designed an antenna which Godley used with great success in Scotland. He heard several American Ham stations, including my station, "2BML", at Riverhead, New York, operated by a fellow engineer, R. B. Bourne. Godley's write up in the Ham magazine "QST" mentioned the wave antenna as the "Beverage" antenna [1, 2]. It has been stuck with that name ever since. [In the wave antenna, a wire erected a short distance above the earth, the effect of the low conductivity of the earth would cause a current induced in the wire due to the wave tilt. However, the presence of the earth would add capacity, so that the current in the wire traveled at less than the velocity of light. If the antenna were too long, the current induced in the wire would lag in phase and eventually would decrease the current at the receiver. The wave antenna would not work in free space, however, because there would be no wave tilt to introduce a current in a horizontal wire!]



Rocky Point, Long Island Transmitting Station, one week after its formal opening by U.S. President Warren Harding on November 7, 1921.

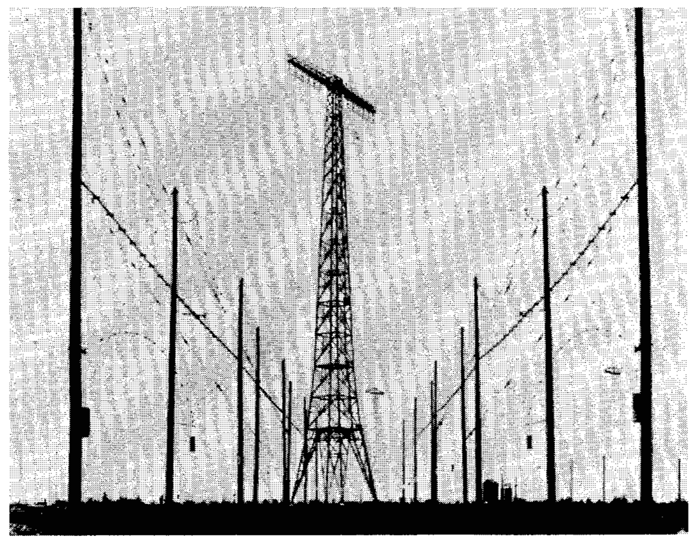
Marconi did not believe that the short waves were necessarily useless, so in 1924 he established a transmitter at Poldhu, Cornwall, England. This was the same location that was used for his successful transmission to Newfoundland in 1901. He started on 90 meters, then 60 meters. The signals were heard at great distances during the night, as expected. However, in October 1924, Marconi tuned the Poldhu transmitter to 32 meters. Much to the astonishment of everyone, including Marconi himself, the 32 meter signals were received over great distances at night but also in *daylight*! For the first time, here was an economical way to establish long-distance daytime transmission. Breit and Tuve in America, and Sir Edward Appleton in England, using different methods, simultaneously discovered the ionized so-called F layers above the Kennelly - Heviside, or E layer. I knew Prof. Kennelly, and also met Sir Edward Appleton in London, in 1960. His greeting was, "Hell, I thought you were a statue!"

In 1921, America, England, France and Germany all wished to establish radio communication with Rio de Janiero and Buenos Aires. Since there was not enough traffic to warrant four stations, America, England, France and Germany agreed to share a single station,



The 200 kiloWatt Alexanderson Alternator Transmitting System at Rocky Point, Long Island. One of the 410-foot multiple-tuned long-wave transmitting antenna towers is in the background.

so they formed an agreement, known as the "AEFG Consortium", to combine their service to South America. In 1922, I headed an expedition to Brazil to determine whether a service could be established due to the very heavy atmospheric static due to thunder storms. I found that the static was so strong at Rio that direct service on the low frequencies was not possible. I proposed that a relay be established at Recifi, in the northern part of Brazil, where we found that the static could be overcome by directive reception. Before the relay could be established, Marconi's discovery of the daylight transmission on the short waves solved the problem. My assistant, C. W. Hansell, thought that if 32 meters was good during the daylight hours, 15 meters might be better. He constructed a "Rube Goldberg" transmitter, using pie plates for capacitors and a horizontal half wave dipole antenna about 25 feet long, supported at a height of 30 feet above the ground. For some time this transmitter was received so well, at Rio and Buenos Aires, that all traffic from Europe was relayed via New York. Later, of course, the European countries established direct communication on the short wavelengths. At first, they all crowded around the magic wavelength of 15 meters. For both transmission and reception, the Marconi Co. developed the "Marconi Beam" antenna. It consisted of arrays of vertical antennas, supported from triatics strung between towers 300 feet high. A reflector, consisting of similar wires, was erected behind the antenna wires. A separate array and reflector was required for each frequency. A Marconi Beam system for three frequencies was erected at the Riverhead receiving station. The Marconi Beam served on the basis that such strong signals were received that they seldom faded below the noise level. Dr. H. O Peterson and I discovered that the fading on the short waves was random between antennas separated by a few hundred feet. We established a system consisting of three antennas, separated by about 1,000 feet, with the signals combined in a system independent of phase differences. We called this the "Diversity reception system" [3, 4] It out-performed the Marconi Beam receiver at less than 10% of the cost. We used two types of antennas for reception. Philip Carter, a member of Dr. Hansell's staff at Rocky Point, Long Island, New York, invented the Rhombic antenna for transmission. It was efficient, but "frequency sensitive." Bruce, of the Bell Labs, added the terminal resistor, which made the rhombic antenna aperiodic so it could be used over a wide band of frequencies, although there was some loss of power in the terminal resistor for transmission. However, this made the rhombic antenna ideal for reception. RCA used many rhombic antennas for both reception and transmission. Dr. Peterson developed the so- called "Fishbone" antenna for reception. It consisted of several horizontal dipoles, which were lightly coupled to a two-wire transmission line through capacitors, in order to keep the velocity of the currents high in the transmission line. The antenna was terminated in a resistance equal to the characteristic impedance of the two wire transmission line. Actually, it was equivalent to the wave antenna designed to work on the high frequencies. The fishbone antenna was somewhat more expensive than the rhombic antenna, but it had a better signal-to-noise ratio, since it had fewer side lobes than the rhombic. We used both types of antennas at all of the RCA receiving stations. Many terminated rhombics were used for transmission. Vertical antenna arrays similar to the Marconi beam were developed by the Bell Labs, France and Germany.



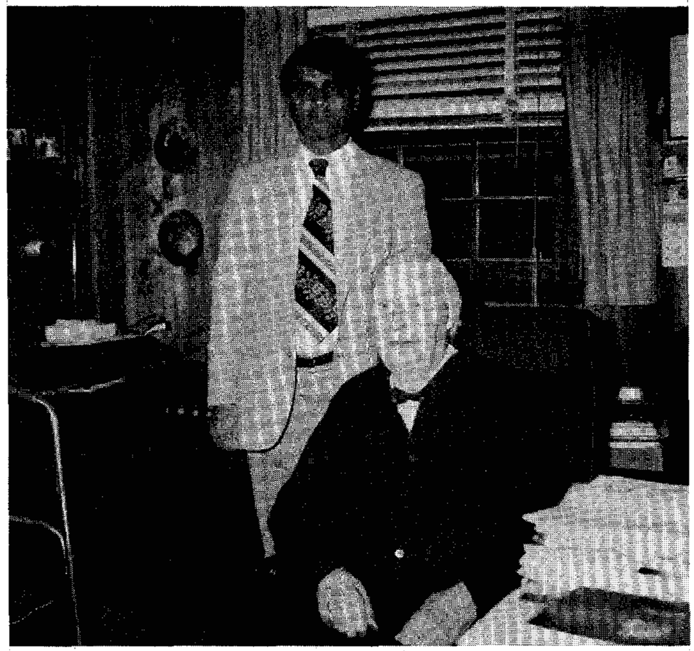
A view of three antenna systems together at Rocky Point, Long Island. One of the twelve 410-foot long-wave antenna towers is at the center, with the shortwave antenna systems, "Type A" (designed by P. S. Carter), on both sides of it. There are two Marconi Beam towers in the background on the right. The Marconi Beam towers, erected in 1927, fell in a hurricane in 1944.

Of course, when television and wide band frequency modulation became widely used, a different type of antenna was required. A popular antenna for television transmission is the "turnstile antenna", invented by George H. Brown of RCA. I was responsible for getting a job for Dr. Brown on the RCA payroll during the depression of 1933 [5] He was a winner, including serving on the RcA Board of Directors. George wrote a very interesting book entitled, *And Part of Which I Was - Recollections of a Research Engineer"* [5].

A popular antenna for reception is the "Yagi" antenna. I met Professor Yagi in Tokyo many years ago. You will find most of the antennas which I have mentioned in the *Proceedings* of the IRE and AIEE. According to my memory, the above describes most of the antennas used for international communication. Detailed information may be found in books by Zenneck, Terman and others. Satellites gradually took over the international traffic. All RCA stations were shut down in 1978.

Some of our inventions are still in use. In the far North, high frequencies are erratic and sometimes

Harold Beverage with John Marshall Etter (on the left), the Radio Engineer in charge of both the Rocky Point Transmitting Station and the Riverhead (Long Island) Receiving Station at the time of their final closings in the late 1970s.



Probir K. Bondyopadhyay (standing) visiting Harold Beverage on the occasion of Beverage's ninety-fourth birthday in October, 1987.

fade out for days at a time, due to sunspot activity. Low frequencies are used in the far North, using wave antennas. This includes use by the Signal Corps and Coast Guard in Alaska and Greenland. The Russians use wave antennas on their long-haul arctic circuits.

The diversity receiving system is still used for reception from satellites, to correct for the phase shift due to the "Faraday effect", when the signals pass through the ionosphere.

When I graduated from the University of Maine in 1915, I was offered two jobs. The first, playing trombone in Loews theatres, at $22 per week, and the second, testman for the General Electric Company, at Schenectady, New York, for 20 cents an hour per week of 56 hours, which amounts to $11.20 per week or $560 per year. I understand that the "kids" with a BS in EE now start at $29,000 per year, which is considerably more than I received after 43 years of work with GE and RCA. While it was difficult to become a millionaire on my salary, I am happy to have been employed during the pioneering days of wireless communication development. It was easy to make useful inventions, and to meet many of the old pioneers [6] I was privileged to meet Marconi, Steinmetz, Langmuir, Cooledge, H. J. Round, Yagi, Sir Watson Watt, Sir Edward Appleton and many other famous people.

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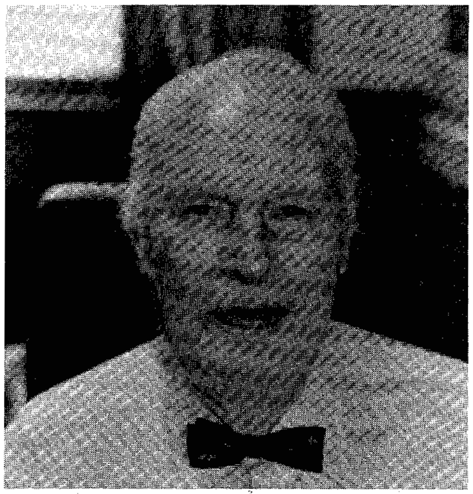
About the Author



Harold Henry Beverage (A 1915, M 1923, F 1928, LF 1958), the world's oldest living antenna engineer, was born on October 14, 1893, in a farm on the island of North Haven, Maine. He was very interested in the early experiments by Marconi with "wireless". In 1908, he constructed a receiver with a galena "cat-whisker" detector, with which he was able to receive signals up to 1,500 miles away at night. At an early age, he decided that he would become a radio engineer rather than a farmer. He received his BSEE degree in 1915 and D. Eng. in 1938, both from the University of Maine. He joined the General Electric Company as a Testman (1915-1916). He was in charge of the Communication Receiver Laboratory, Radio Corporation of America (1920-1929). He became the Chief Communications Engineer, RCA Communications, Inc. (1930-1932), and then Chief Research Engineer (1932-1940), Vice President of Research and Development, RCA Communications, and Director of Radio Research for RCA Laboratory (1941-1958). He retired in 1958.

He received the Morris Liebmann Award in 1923 for "development of directive receiving antennas." He was the President of IRE in 1937, and received the IRE Medal of Honor in 1945 and the Lamme medal, AIEE, 1956 for "his pioneering and outstanding engineering achievements in the conception and applications of principles basic to progress in national and world-wide radio communication. Other awards include Achievement Award, IRE Professional Group on Communications Systems, 1958; A Century of Progress, IEEE, 1984; Armstrong Medal, Radio Club of America, 1938; Modern Pioneer Award, National Association of Manufacturers, 1940; Certificate of Appreciation, Signal Corps, 1944; Presidential Certificate of Merit, 1948; Fellow, American Association for the Advancement of Science, 1954; Eminent Member, Eta Kappa Nu, 1955; Honorary Member, Tau Beta Pi, 1959; Marconi Gold Medal, Veteran Wireless Operators Association, 1974; Pioneer Award, Radio Club of America, 1976; Alumni Career Award, University of Maine, 1976.