Improvement of Radio Equipment During World War I

1. TRANSMITTERS[1]

There was little wartime improvement of damped-wave radio transmitters. This was due to the early realization by our naval radio engineers of the superiority of continuous wave transmissions. During the war the Navy purchased additional spark transmitters only because of insufficient manufacturing facilities for the production of undamped equipment of lower powers, and for fitting aircraft.

The war stimulated the development of three types of transmitters: The arc, the alternator, and the lower-power vacuum tube. The higher powers required for long-distance communication necessitated continued efforts to increase the power of both the arc and the alternator. Requirements for lightweight voice transceivers for the submarine chaser and aircraft programs spurred the development of electronic equipment and resulted in the later development of vacuum tube transmitters of all sizes.

The arc transmitter was progressively increased in power from the 30-kw. that had been installed in Arlington, to 100 kw. for Darien, to the 200 kw. for Chollas Heights, to 350 kw. for Pearl Harbor and Cavite, to 500 kw. for Annapolis and, finally to 1000 kw. for Lafayette. Plans called for 2,000 kw. at the never-to-be-built Monroe station. The Federal Telegraph Co. had wailed, protested, and almost refused to construct the 100-kw. arc for Darien. The Navy would not compromise, firmly believing that the power of this type of transmitter could be increased manyfold. Opposition decreased as success was obtained in constructing the higher and still higher powered equipments. By the time the contract for the Lafayette transmitter was made, Mr. L. W. Fuller, Chief Engineer of the Federal Co., believed he could successfully design an arc of 5,000 kw.[2]

In explanation of this optimism, he said that at the time he went with the Federal Co., in 1912, they had succeeded in building a 30 kw. which would deliver a proportionate amount of power to the antenna as compared with the lower-power ones. When the power input was increased beyond this, it had all gone into the production of heat. The higher powers were obtained by increasing the size of the magnetic field between the two electrodes to permit it to deionize the arc gap every radiofrequency cycle. This was accomplished by constructing a small size model of the magnetic circuit for each arc power rating. It was found that the flux density checked with that predicted by the model. Therefore, it was only necessary to provide an adequate magnetic field by proper increase of the sizes of the electrodes and the volume of the arc chamber.[3]

However, the arc was inferior to the alternator as a transmitter. At that time it utilized two frequencies for normal operation, a transmitting one and a compensating one, it emitted many harmonics, and had a slight frequency variation that made it somewhat the equivalent of a broad-wave transmitter.[4] The alternator had no harmonics and transmitted but one sharply defined frequency. Arcs could be built in sizes adapted to shipboard installation, but this was not feasible with the alternator. The higher power of the second alternator installation at New Brunswick and the improvements made by Alexanderson in that installation made it the most sought after transmitting equipment of the time for long-distance point-to-point circuits. These two types of transmitters, each used for the purposes best adapted, would have remained supreme for years except for one thing, the controllable oscillating properties of the three-element vacuum tube.

2. VOICE MODULATED TRANSCEIVERS

Consideration had been given to the construction of submarine chasers sometime before our entry into the war. The design was completed and contracts for hull and engine construction were entered into on 2 April 1917. It was planned to construct over 300 of these seagoing boats and to equip them with the latest devices available to enable them to be used in submarine hunter-killer groups. Their tonnage restricted the size of the crew and necessitated the utilization of as much automatic equipment as possible. Visualizing the need of radio telephonic equipment for this "mosquito fleet," the Bureau of Steam Engineering, in March 1917, contracted with the Western Electric Co., for 15 radiotelephone transceivers for experimental purposes. This equipment, assigned the Bureau designation, CW 936, was well known to all naval communication personnel during the war and the "twenties."[5]

This first completely successful voice modulated equipment was designed for use on any one of five frequencies. The frequency could be shifted to any one of these, all of which were within the band 500-1,500 kc., by means of a simple frequency change switch which cut in different fixed values of capacity and inductance for each of the five switch positions. This equipment quickly came into demand by all types of ships in both our own and the Royal Navy. Over 2,000 of them were purchased and installed on combatant vessels. More important, it was the predecessor of the modern vacuum tube transmitter and provided our personnel with the operational knowledge that would later cause them to demand tube transmitters of higher and higher powers, covering broader portions of the frequency spectrum. It was the herald of broadcasting, television, and reliable and economical long- and short-distance radiotelephony. Greatly improved voice and telegraphic equipments would be developed in the coming years but, as late as 1930, the fleet was placing great dependence upon the CW 936, by that time modified for radiotelegraphic transmission and used for tactical purposes.[6]

3. RECEIVING EQUIPMENT[7]

With the advent of the vacuum tube as a detector, amplifier, and radiofrequency driver (heterodyne), it was normal practice to house separately the primary and secondary circuits (commonly called the receiver), the detector, the driver, and the amplifier, and to connect them through external binding posts. This is understandable considering the large quantity of receivers, using crystal or other types of detectors, being employed at the time tubes came into general use. The Navy, with its limited radio budget, was unable to provide sufficient vacuum tube devices for several years. They were provided ships and stations in small quantities and their use was restricted to the reception of continuous wave signals or for amplifying the weakest signals.

More improvements in radio receiving equipment and techniques were made between 1913 and 1917 than in the previous 15 years. Many of these stemmed from the work of, or the assistance rendered by, naval radio engineers. Except for the complicated patent situation, further improvements would have been realized. The development of military radio equipment by commercial interests was discouraged by the Navy's decision to design and if necessary to develop and build equipment suited to its own particular requirements. The closure of the commercial and amateur stations in 1917 curtailed the market for radio equipment. These factors combined with the patent situation, still further discouraged commercial development.

Between late 1915 and early 1918 a court decision protected manufacturers from infringement suits in the provision of equipment under Government contracts. With this protection, they were extremely willing to manufacture radio equipment of Navy design and under rigid Navy specifications. In 1918 this decision was reversed and the radio manufacturers again became concerned over the possibility of litigation and were unwilling to complete their contracts. The Navy, lacking the manufacturing facilities to produce the large quantities of radio equipment necessary for the prosecution of the war, required the services of the commercial manufacturers. Assistant Secretary of the Navy Franklin D. Roosevelt issued the famous "Farragut Letter" which assured contractors that the Government would assume liability in infringement suits. With this assurance they continued manufacturing the needed equipment.[8]

The burden of the design and development of receiving equipment continued to fall largely to the Navy, with some assistance from the Western and General Electric Cos., and the National Electric Supply Co. This design and development was the responsibility of the Washington Navy Yard where it was assigned as a function of the Radio Test Shop. In 1915 this facility was placed under the direction of Lt. (jg) William A. Eaton, USN, an officer possessing an "especial technical education, an investigator and inventor of high order."[9]

Too little credit has been given Eaton for the work performed by his group which consisted of Gunner T. McL. Davis, USN, Expert Radio Aids Priess, Israel, and Horle, Radio Electricians Shapiro, Carpenter, and Worrel, and Prof. L. A. Hazeltine, consultant. Despite other pressing duties[10] they were able to design and develop superior receiving equipments and to provide commercial companies with ideas which lead to their development.

Early in 1916 it was decided to redesign the type A and B receivers. The specifications for the new receivers were provided to the Washington Navy Yard and to the National Electric Supply Co., of Washington, D.C. The Navy Yard had completed the new designs of these receivers before the National Electric Supply Co. submitted models of their two receivers, the CN 208 and CN 239. It was discovered that the induction coils of these were superior to those used in the Navy designs. Production of type A, 1917, had commenced but was stopped after 40 receivers had been manufactured. Type B, 1917, was not placed into production.[11] Modified specifications were immediately issued and the Navy Yard redesigned and developed their sets, designated the SE 95 and SE 143 receivers. The Navy and the National Electric Supply Co. equipments were comparable. The SE 143 and CN 208 sets which covered the most used frequency range, 100-1,200 kcs., became the Navy's wartime utility sets. They were manufactured in large quantities by several manufacturers. The SE 95 and CN 239 covered a range of 30-300 kcs. Numerous modifications to both of these equipments were made to meet specific requirements.

Toward the end of 1918 the SE 1220 receiver was designed by the Radio Test Shop. Inductive coupling was used for the first time in Navy-designed equipment. This receiver, which covered the frequency range 45-1,000 kc., contained tuned and untuned secondary coils either of which could be used by proper positioning of a double-pole, double-throw switch. The purpose of the untuned secondary was to provide close coupling between the primary and secondary sets to facilitate initial signal pickup. This receiver was superior to the SE 143, but before it could be placed in quantity production Professor Hazeltine devised his method of neutralizing undesired oscillations. The SE 1420 receiver, embodying this neutrodyne method of reception, was then designed. In this receiver the vacuum tube detector circuit was made an integral part of the receiver, thus eliminating the need of this component as an additional item of equipment. The untuned secondary circuit was eliminated and, by thorough shielding, it was made highly selective and proofed against the pickup of local interferences.

With several minor modifications the SE 1420 became the Navy standard mediumwave receiver and remained in service for many years. Additional receivers were designed upon the same principles, covering other frequency ranges or for special uses in aircraft, or with direction finding equipment. One of these, the SE 1440, designed for use with the radio direction finder, was the first equipment in which the audiofrequency amplifying circuit was an integral part.

The increased reliability of vacuum tubes brought about by the General and Western Electric Cos. made their use as detectors more feasible. Early tube detector units were purchased from De Forest but their construction was not satisfactory and Eaton and his associates, assisted by Western Electric Co., engineers, developed the SE 838. This was soon improved by Navy engineers and designated SE 1071. The growing practice of making the detector circuit an integral part of the receiver soon made these devices obsolete.

Early audiofrequency amplifiers were purchased from De Forest. These facilitated the reception of weak signals but, like his detectors, they were not entirely satisfactory. The Radio Test Shop redesigned his device, making it a two-stage audiofrequency amplifier, designated SE 1000. During the life of this amplifier it underwent six improvement modifications and was Navy standard equipment for years.

The urgent need of high-power amplifiers for reception in aircraft resulted in the development of six-stage amplifiers containing three stages of radiofrequency amplification, followed by a detector circuit, and then two stages of audiofrequency amplification. The first of these completed was the SE 1613 (100-300 kc.). It was immediately improved and redesignated SE 1615 (30-100 kc.). The SE 1617 (18-43 kc.) followed. The SE 1405 (45-150 kc.) was designed for use with aircraft radio direction finders.

The radiofrequency driver was a low-power generator of continuous waves which supplied the local oscillations for modulating incoming continuous wave signals to make them audible. This device was necessary for use with the Navy receivers not employing autodyne reception. Only three types were developed, all of which contained similar circuitry.

Eaton and his assistants, with the aid of Hazeltine, were successful in providing the Navy with receiving apparatus as good as, and in most cases better, than that used by any other nation, and vastly superior to any equipment in commercial use. They also made it possible to procure this apparatus in large quantities at a high production rate and at very low cost.[12]