



The cover of Western Electric News for February, 1919. It depicts two-way air/ground radio communication. Note the trailing antenna on the lead aircraft. (Original in color.)

THE BEGINNINGS OF VACUUM TUBE RADIO AT WESTERN ELECTRIC

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The vacuum tube changed wireless radically after 1914, opening a new era which lasted until well after World War II. Many of the new developments originated in the Research Branch of the Western Electric Company at 463 West St., New York. Here men with familiar names like Colpitts, Hartley and Heising devised most of the basic circuits used in radio. It is remarkable that so much of the early technology emerged from a company which had not previously been active in wireless communications. This is the story of those new beginnings, told mostly by the men who were there at the time.

Background

The series of commercial companies which exploited Alexander Graham Bell's inventions after 1875 went through several name changes, and the Bell Telephone Company is used here to identify them all. Holding patent rights to the most important elements of the telephone, the company prospered and was able to maintain a strong but by no means impregnable position in this developing market. In 1878 the company was fortunate to gain Theodore N. Vail as General Manager (Fig. 1). It was largely he who guided the Bell company into a much stronger position.

Vail realized that when these basic patents expired in the 1890s the company would be thrown into direct competition with the growing number of independents and that they needed to strengthen their foundations before this happened. He sought to consolidate their position by establishing top-class research and development facilities. His strategy included taking over Western Electric, one of the larger telephone equipment manufacturers, but perhaps his most astute move was to promote long-distance telephony. At a time when there were few connections between towns Vail foresaw that the company controlling these links would be able to dominate the market.

For convenience in raising capital the American Telephone and Telegraph Company was established in New York in 1885 to take on the long distance communication side of the company's business. A.T. & T. eventually became the parent company of the Bell system at the end of 1899.

John J. Carty (Fig. 2) started in the company as a boy switchboard operator and worked his way up to become Chief Engineer of A.T. & T.

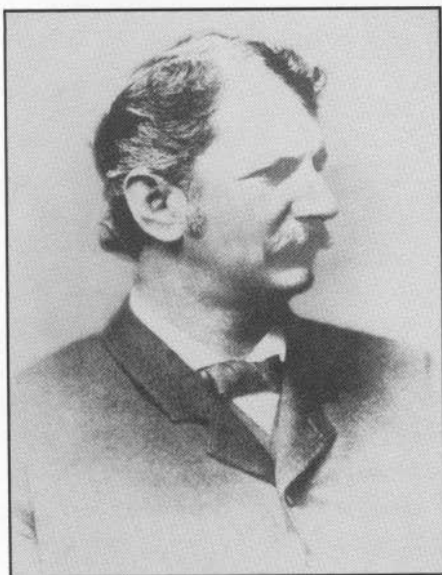


Figure 1. *Theodore N. Vail, General Manager of the Bell Telephone Co. after 1878.*

in 1907. Carty was particularly active in implementing Vail's desire for more and better long-distance services.

As their understanding of line transmission principles progressed, ever increasing distances became possible. Inductive loading made it possible to link Chicago with New York and by 1911, using loaded 0.165-inch diameter conductors, they reached Denver. Even this remarkable achievement was short of the desired "coast to coast" objective, and it became evident that the next step would require amplification.

Late in 1909, during talks with the management of the Panama-Pacific Exposition scheduled to open in San Francisco in 1914, Vail & Carty virtually promised that they would have a telephone working between

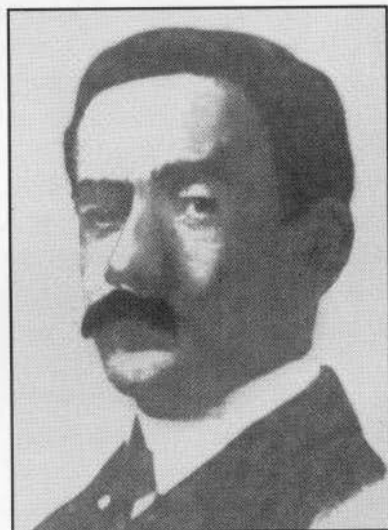


Figure 2. *John J. Carty, Chief Engineer of A.T. & T. in 1915.*



Figure 3. *Thomas A. Watson speaking, in San Francisco, over the transcontinental telephone line at its opening in January, 1915.*

New York and San Francisco. On their return to New York it is said that Vail told his engineers *"We've promised it; now you find a way to do it"* (9).

In the potent research laboratories of the Western Electric Company at 463 West St., New York efforts were being made to find a suitable amplifier. In 1903 H. E. Shreeve, of the mechanical department, coupled an electromagnetic receiver directly to a carbon microphone transmitter and succeeded in amplifying an input signal. However, there was so much distortion that few could be connected in tandem. Harold deForest Arnold had developed mercury-arc discharge tubes controlled by transverse magnetic fields which were capable of amplification, but these required expert attention and were not suitable for use in the field. In October, 1912 John Stone Stone and Lee de Forest demonstrated the Audion to Western Electric engineers. This was the second time it had been shown to them, but on this occasion Arnold recognized the inherent possibilities in the crude device. Lee de Forest was paid \$50,000 by Western Electric for the rights to use the Audion for telephony, and they started development work to make it suitable as a line amplifier.

By July, 1914 they were able to demonstrate the transcontinental telephone line promised by Vail. Three circuits were installed, one using the Shreeve mechanical amplifier, a second with Arnold's mercury-arc amplifiers, and the third with the vacuum tubes developed from the Audion. All three circuits worked, but the vacuum tube won the contest (3). At the official opening, Alexander Bell in New York spoke to Thomas Watson in San Francisco, repeating his well-known statement, *"Mr. Watson, come here, I want you"*, to which Watson replied, *"It would take a week to get there now!"* (Fig. 3).

referred to as a "repeater" in conformity with the usage of the time. R. V. L. Hartley explained the idea of "sidebands" to him, and although Heising was not sure who had conceived the notion he believed that it had been hatched within the Western Electric laboratories. To quote Heising:

"The knowledge of sidebands seems to have been generally confined to our engineers for some time. As much as two years after my introduction to sidebands their presence was not known by all prominent outside radio engineers as I learned by observation, but was generally spreading. When this country entered the war and we helped educate army and navy men in radio we had to point out the sidebands even in the case of their expert radio aids" (2).

Heising was probably the first to use the word "modulation" in the telephone/radio sense.

The potential of the vacuum tube was already well established within the company. Several important basic circuits had been developed and patented, including the push-pull amplifier by Edwin H. Colpitts in 1912, and a stable vacuum-tube oscillator using a tapped-tuned inductor by Ralph V. L. Hartley in August, 1914. Soon afterwards Colpitts had devised its capacitive equivalent.

The Vacuum Tube Telephony Transmitter

Western Electric management now believed that a high-power vacuum-tube telephony transmitter should be possible, and by the end of 1914 it was decided that Hartley's group should develop a prototype.

Heising was given the job of investigating parallel operation of existing telephone-repeater tubes to see whether it was possible to multiply their output power. By the time he had four connected in parallel in an amplifier circuit he was faced with "singing," but found that this could be stopped by putting resistances in the grid connections. He was able to get about 1.5 watts from the combination, which was about four times the output from a single tube; this encouraged him to believe that larger powers could be achieved in this way.

A group under H. D. Arnold started work on a large vacuum tube capable of dissipating about 25 watts (to be known as the type W or 204B - see Fig. 5). Hendrik J. van der Bijl determined the electrode sizes and dispositions while Arnold and Weinhart did the mechanical design and construction. This tube was characterized by its anode, which was formed by bending nichrome tape back and forth to form two plates (as proposed by Arnold) which could be heated by an electric current

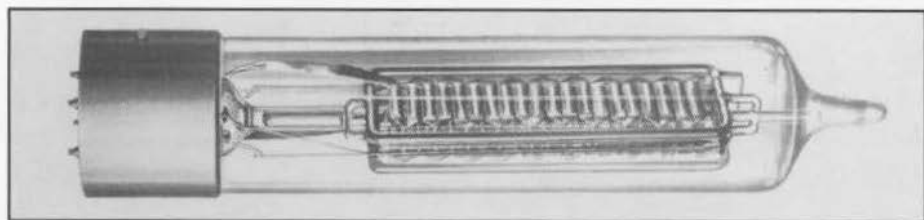


Figure 5. *The transmitter power tube (Western Electric type W) used in the telephone tests.*

during the exhausting process to help remove occluded gases. The filament was made of platinum ribbon coated with barium and strontium compounds and strung across a tall rectangular glass frame (developed by A.M. Nicolson). There were three sections, each in the form of an N, connected in parallel. This resulted in nine lengths of filament, zig-zagging from top to bottom (2).

At that time amplifiers were operated under what was later to be described as class-A conditions (Heising's class C amplifier came later in 1916). Heising tried resistance coupling the RF-power-amplifier stages but soon found that there was little gain due to the high shunt capacitances. He tried tuned-circuit coupling and encountered "singing," which he was able to control only with difficulty.

Heising makes the point that components were expensive in those days, and the need for every tuning capacitor in a circuit had to be weighed against its cost — each crude "Blitzen" or "Mascot" 750 pF variable condenser cost \$5.00, and a Marconi 10,000 pF variable with rubber dielectric cost between \$25 and \$50 each.

The early radio-telephony experimenters had generally modulated the radio-frequency carrier by absorbing part of its energy in a microphone (variable resistance) connected in series with the antenna. In May, 1914 Colpitts patented a grid-modulated oscillator for amplitude-modulated transmission, and van der Bijl later developed the grid-modulated amplifier (patented in August, 1915) which was used during these tests. At this time low-level modulation, followed by linear RF-power amplification, seemed a natural choice.

The Montauk Point Transmitter

It was decided to use eighteen power tubes in parallel to produce an output power of about 150 watts. The drive voltage for the output amplifiers was sufficient to make the grids conduct during part of the cycle. As a result the grid-bias battery voltage rose to about 2 V/cell, and had to be normalized by shunting the battery with a leak resistance. They had numerous difficulties due to the long interconnecting leads which had sufficient inductance to provoke "singing." Sorting the problems out



Figure 6. *Montauk Point test site - the hut on the left was the engine room.*

was complicated by the fact that the handmade power tubes were scarce, and they had to take care not to overload them.

The transmitter was to be installed at Montauk Point (at the extreme north-eastern end of Long Island), favored presumably because of its proximity to New York and because it was almost surrounded by sea. A receiving site was found at Wilmington, Delaware, in the Dupont building (about 250 miles away) on the top of which was a suitable antenna.

A 25-foot square timber frame building was erected (Fig. 6) to house the transmitting equipment, together with a nearby shack for three engine-driven dc generators, providing 110 V for lighting, etc., 500 V for the power amplifier anode supply, and a low voltage for the filaments. Two 165-foot high steel towers, erected 300 feet apart, supported the antenna.

The transmitter circuit, as recollected and drawn by Heising in 1938, is reproduced in Fig. 7. Except for the power amplifier the apparatus was constructed in four boxes, as seen in Fig. 8. The Hartley oscillator mounted in the top right hand box used a low-power telephone-type tube.

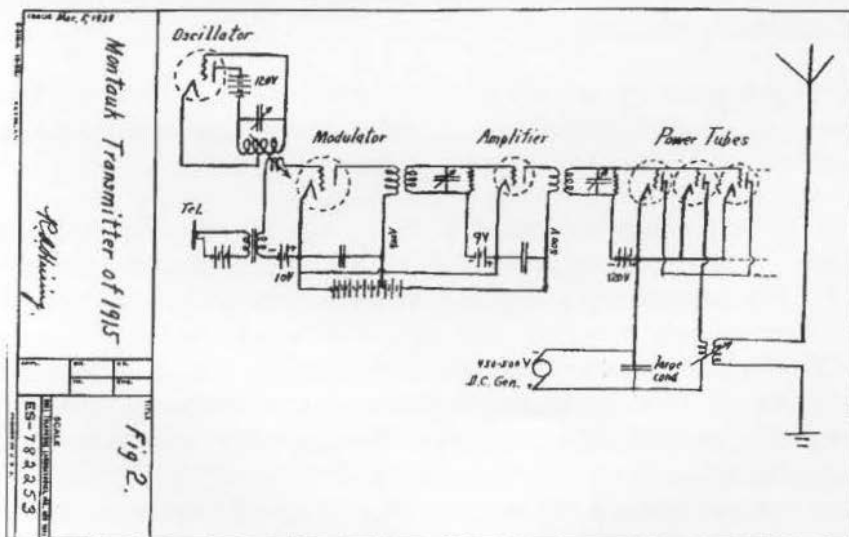


Figure 7. *Montauk Point transmitter - sketch made by Heising in 1938.*

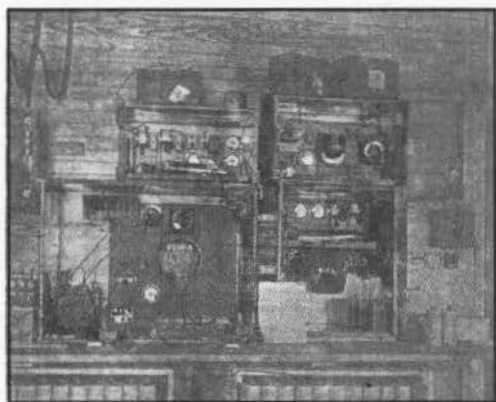


Figure 8. *Montauk Point transmitter. Oscillator top right side, modulator bottom right side, first amplifier top left side.*

The van der Bijl modulator (grid modulation) in the lower right case used a single power tube, which can be seen lying on its side above the plate load coil. The first stage linear amplifier in the top left box also used a single power tube lying on its side. The lower left box "...has a tuned circuit and certain controlling resistances which enter into the transmission system." (1)

The eighteen type-W power-amplifier tubes can be seen lying horizontally in the rack on the extreme left side of Fig. 9. The power tubes in these early tests had no bases and were wired directly into circuit. The oscillator, modulator and amplifier stages drew their anode supplies from batteries of "No. 6 dry cells of which several barrels were used." (2)

Preparations on site progressed according to plan until early in May, 1915 when it was heard that Dr. Irving Langmuir was due to deliver a paper to the Radio Institute on 7 April, and it was thought that this might deal with radio telephony.

"In order that it could not be said that anything Langmuir disclosed at this meeting was instrumental in assisting or contributing to the success of our tests, we had to speed up our preparations." (2)

By 23 March they succeeded in delivering 160 watts into a dummy antenna in the laboratory and had installed the equipment on site by 1 April. The power-supply engine gave some trouble and on 3 April a sleet storm brought down the antenna and the telephone lines.

Carty had already arranged for a party including Prof. R.A. Millikan, Col. S. Reber, F.B. Jewett and B. Gherardi to assemble in New York and travel to Monauk Point on Sunday, 4 April. The antenna could not be raised as the cable passing over the top of the tower had slipped off its sheave and was jammed. In freezing weather Lloyd Espenschied risked his life to climb up the tower on steps, (which had been put on upside down) to rectify the problem.

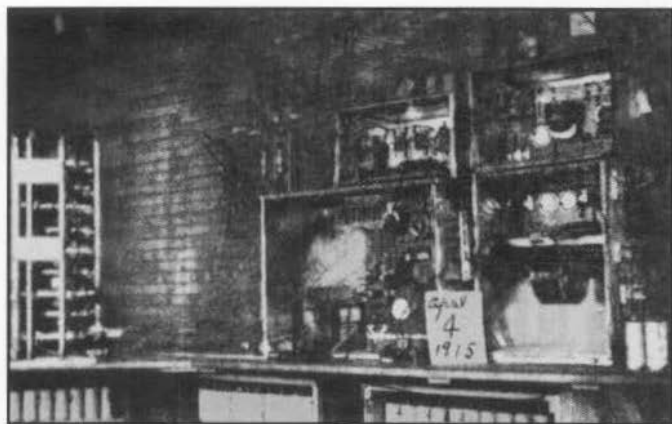


Figure 9. *Montauk Point transmitter - the 18 power tubes were laid in the rack on the left. The batteries of #6 dry cells can be seen under the equipment benches.*

That evening they were able to transmit telegraph signals to Wilmington with reception confirmed by telephone. At this point *"Mr. Arnold took possession of all microphones so that no telephonic words could be transmitted until Mr. Jewett or Mr. Carty had been first in this respect."* (2)

Tests were made with one to eighteen power tubes to determine the effects of varying the power output. The antenna current with all eighteen tubes, at about 170 kHz, was four amperes C.W. and six amperes fully modulated. Full power was not achievable, as the anode-supply voltage had to be limited to about 430 V to avoid having the tubes break down.

The visitors were able to talk to Hartley at Wilmington with their words repeated back to them via a third party over the telephone. The line was then connected to the output of the receiver at Wilmington so that listeners at Montauk could hear the quality of reception. The process was then reversed using the telephone line to modulate the Montauk transmitter so that those at Wilmington could hear themselves transmitted from Montauk. The official party then moved to the receiving station where similar tests were repeated.

Several of the development team attended the talk given by Langmuir at the I.R.E., almost entirely devoted to tubes and theories. Langmuir concluded with some remarks on work he had done using a vacuum tube as a power oscillator with a second tube to modulate the output, but disclosed no details. The Western Electric team concluded that in this sphere they were well ahead of General Electric.

Transatlantic Radio Telephony

Carty was now determined to demonstrate that wireless was suitable to extend the telephone across the Atlantic, and a conference in his New York office was arranged to discuss the details. It was already evident that much more power would be required, but it was believed that this could be achieved by connecting an even larger number of tubes in parallel. A longer wavelength would be required to reach around the earth's curvature, and this demanded a much bigger antenna than that used at Montauk

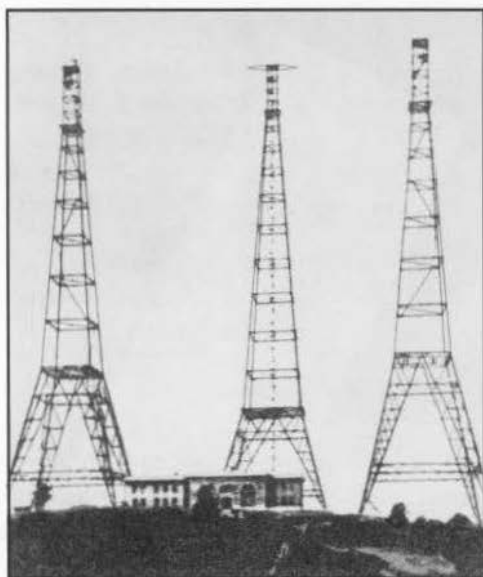


Figure 10. *The 600-foot masts at Arlington(1915).*

Point. The Arlington naval radio station had one of the largest antennae in the country (600 feet high...see Fig. 10) and Carty hoped to persuade the U.S. Navy to let them use it for these tests.

Before committing themselves the navy wanted to be assured that the tests would be worthwhile, and a demonstration of the Montauk equipment was arranged for 3 and 4 May, 1915. Captain Bullard and Cmdr. Hepburn of the Bureau of Steam Engineering came up to observe the tests, but said nothing. In Heising's own words,

"Captain Bullard told me later that year that he had no faith in our being able to talk across the Atlantic when the subject was first broached to him. He felt it was the idea of people who knew nothing of radio. He didn't expect telephone people, of all people, to be able to do it. It was only the fact that the engineers who approached him had unquestioned reputations in the engineering world that prevented him from throwing them out and dismissing the proposal from his mind. He therefore listened politely to what they had to say and witnessed the tests without being convinced. They seemed to be so enthusiastic about the project, however, that he finally thought that as it was their own money they wanted to spend they should be given whatever opportunity there was and he would look into the matter further. And so we were definitely launched on the transoceanic experiments." (2)

It was decided to try extended distance tests from Montauk Point, and a receiving station was set up at St. Simon's Island on the southern coast of Georgia. The distance would thus be increased to almost 1,000 miles, besides which it was a good location to bring visitors who could



Figure 11.

The temporary building erected at Arlington for the radio-telephony tests.

stay on nearby Jekyll Island where some of the top executives, including Vail, kept winter residences. Spliced wooden 120-foot poles were brought in and erected to support the receiving antenna. By now several of the power tubes had failed and they had to do the best they could with twelve to fourteen. Fortunately these could all withstand 600 V and they were able to get through. Lloyd Espenschied reported as follows:

"After listening a number of weeks to determine the best hours for reception, success was attained and there was heard through the static the human voice which had been spread so thinly on the ether at Montauk Point. Again, for the sake of completeness, the received voice was put on a telephone line and transmitted to other listeners in New York. Again, voices could be heard, but much patience was required in waiting for some brief lull amid June's troublesome atmospheric noises." (3)

The Arlington Transmitter

A timber-framed building was erected next to the Government radio station (Figs. 11 and 12). The Navy agreed to allow their 600 Vdc supply to be extended to a local switch board so that they could regulate the generator during tests. They anticipated having at least 500 power

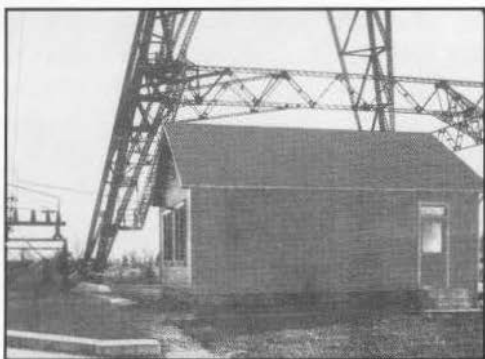


Figure 12. *The radio-telephony transmitter building showing the download and antenna switching.*

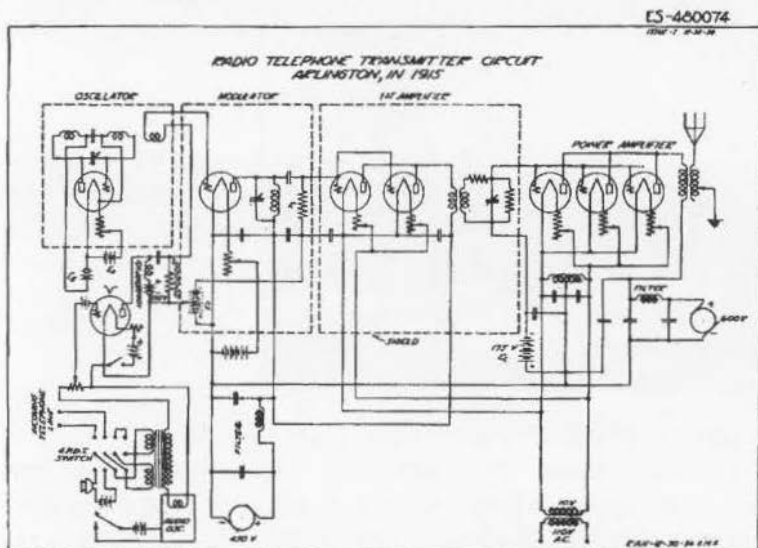


Figure 13. *The circuit of the Arlington telephony transmitter.*

tubes in parallel to reach the desired output power. With each nine-volt filament drawing 4.8 - 5 amperes (Tyne states 4 - 4.5 amperes) the only economical means of supplying so much current was to use an ac supply with a transformer mounted close to the power racks. Heising investigated various ways to minimize the injection of hum from the filaments, and patented the balanced-filament supply which was used at Arlington (U.S. patent 1,432,022).

The design of the transmitter fell largely upon Heising, and the circuit diagram which he reproduced in 1930 is shown in Fig. 13. He decided that the best way of dealing with the enormous number of tubes would be to mount them horizontally, in much the same way as at Montauk, but with ten racks each carrying fifty tubes. As each of these would have to dissipate about 4 kW, cooling fans were required to remove the heat. Separate circuit breakers and the 600-volt commutator noise filters were fitted to each rack.

The early stages were mounted in separate boxes with the oscillator and modulator screened on five sides to avoid feedback from the antenna. The Hartley oscillator with its type-M tube occupied the top section of Fig. 14 - its dedicated anode and filament batteries were housed externally. The speech amplifier can be seen in the center compartment, with its associated input transformer, changeover switch and audio oscillator in the lower part. The modulator can be seen on the right hand side of Fig. 15. The anode tuning coil is immediately below the tube and the box at the bottom contained the grid bias battery. The bases of the first amplifier tubes can be seen in Fig. 15, with six in the lower and six in the upper

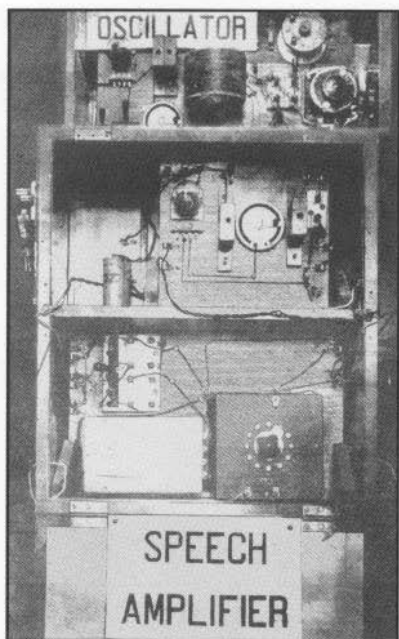


Figure 14. Screened boxes containing the Hartley oscillator with its type-M tube in the top compartment and the speech amplifier in the center, with its input components below.

boxes. Between two and twelve tubes were connected, depending on the frequency and the number of output amplifier tubes in use.

Fig. 16 shows the "front" of the first five racks of power tubes; the unbased tubes were inserted from the rear and the leads passed through the panel and connected to binding posts or Fahenstock clips. Each tube had its own 2/3-ohm filament rheostat (the porcelain discs), and anode and filament jacks for measuring the current. A grasshopper fuse was

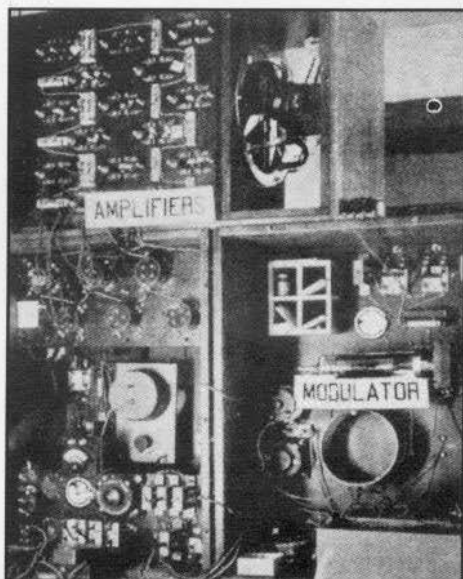


Figure 15. First R.F. amplifier on left side. The nine tubes in the upper compartment were cooled by the fan. The modulator was in the lower right compartment where the tube and output tuning coil can be seen.

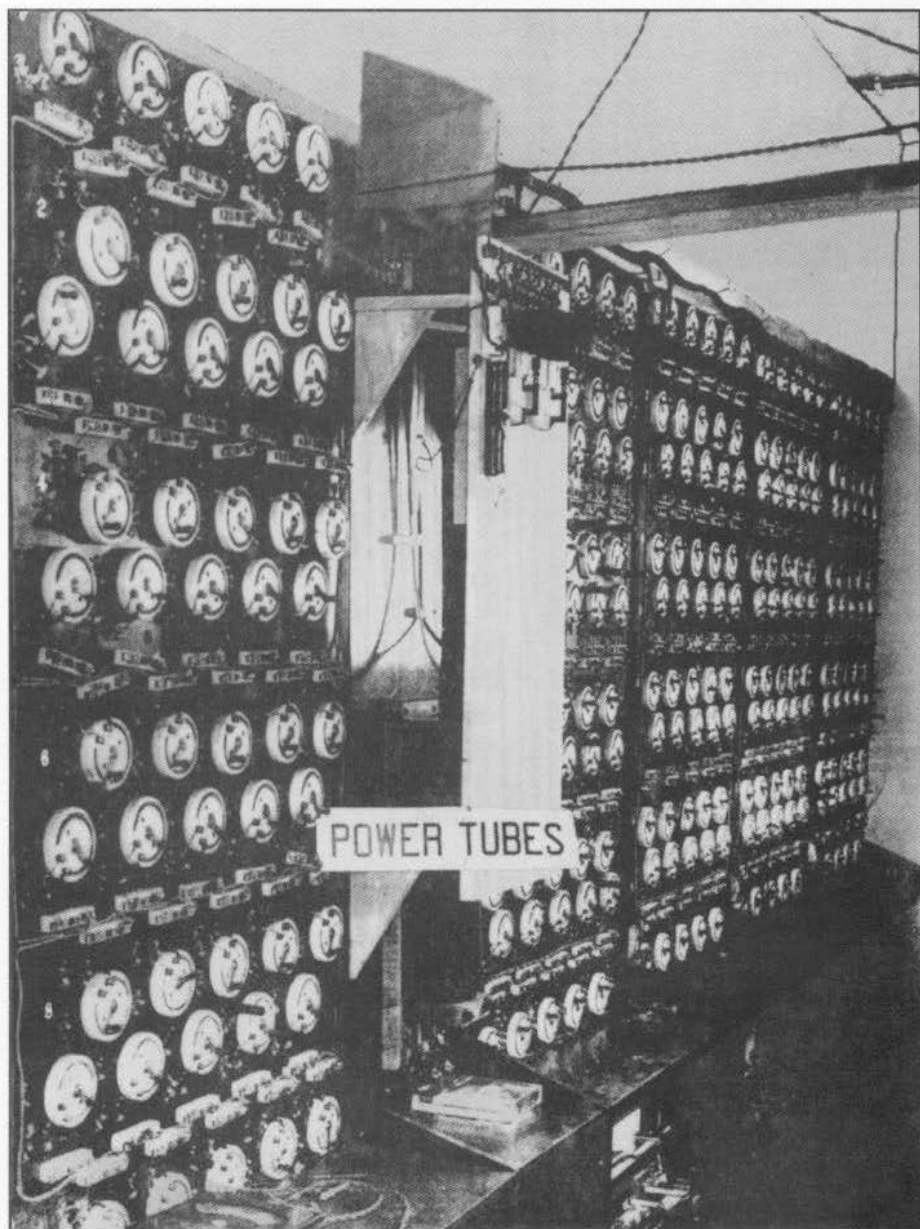


Figure 16. The first five racks of power tubes. The tubes on this rack had no bases and were supported on the other side of the panel with their leads brought through to connectors. The rectangular porcelain blocks between each second row of filament rheostats were the grid grasshopper-fuse blocks. The board between the first and second racks was the distributing rack which held most of the common equipment. The RF input leads came in on the horizontal board at the top of the second rack. The distributing frame is mounted between the first and second racks. Each tube had a pair of jacks to facilitate filament and anode current measurements.



Figure 17. *The rear of the first five racks on the right side, and the front of the second row on the left. The RF connecting leads can be seen overhead. The first three racks in the second row held power tubes fitted with bases.*

included in each grid connection (the rectangular porcelain blocks) so that in the event of a contact between the filament and grid the fuse would blow, giving a visible indication of the faulty tube and preventing a drop in the bias supply, which would have caused overheating in the other healthy tubes. The anode supply was brought in at the base of each rack and had its own switch, circuit breaker, and ripple filter. The RF input leads came in on the horizontal beam, seen crossing the top of the picture, and were connected individually to each power rack via the terminal strip seen just beneath the beam, and mounted at the top of the white board. The white distributing rack held bypassing condensers, the center-tapped choke for the filament-ground point, and part of the input-tuning capacity, and served all racks.

Fig. 17 shows the rear of the first five racks on the right side, and the front of the second five racks on the left. The first three racks of the second row used mounted tubes and had a different component layout. The output from each rack was taken overhead with individual leads to the combiner at the distribution rack in the first row, and from there by means of a single lead to the antenna transformer.

The antenna transformer, mounted in the attic (Fig. 18), was made by Carl Englund and consisted of a fixed antenna coil (about 25 turns) of copper strap wound on a wooden form about four feet in diameter, with

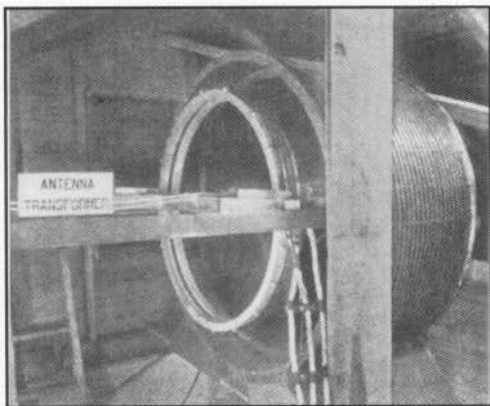


Figure 18. *The antenna transformer, mounted in the attic, was made of strap copper. The sliding primary coil had three turns while the antenna coil had an inductance of one mH. The coupling could be adjusted with the help of the ropes seen in front of the label.*

an inductance of 1 mH. The internal primary coil had only three turns and was arranged to slide into the antenna coil, being moved by ropes leading to a position near the modulator case (ref. 2).

Gaseous power tubes were eliminated during rack testing, but seemed to remain a recurrent source of difficulty throughout the tests. When a second rack was added to the first the power doubled, but when a third rack was connected the power did not increase proportionately. A fourth rack seemed to add nothing and the fifth actually dragged the power down. The problem was the progressive phase shift caused by each rack being connected to its neighbor. The solution lay in taking separate leads to and from the distribution panel to each rack.

The receiving equipment was designed and made by Hartley and R.H. Wilson, assisted by B.W. Kendall. Craft and Colpitts reported the following (1):

"The method of reception was varied from time to time as it was still in process of development. In some cases an amplifier for the high-frequency currents was introduced between the detector and the tuned circuit which was coupled to the antenna. In some cases a low-frequency amplifier was inserted between the detector and the receivers. In some of the later experiments a feed back circuit was used for the detector so that the detector tube itself acted as an oscillation generator as well as a detector. In that case the frequency of the oscillations was adjusted to be the same as those of the oscillation generator at the transmitting station (sic)." (1)

Presumably they were using regeneration in the latter experiments.

First Tests at Arlington

With only about 200 tubes in operation testing began. R.H. Wilson at the U.S. Navy Station at Darien, Panama, was able to hear Arlington over a distance of about 2,100 miles. W. Wilson in San Diego, and

Hartley at Mare Island, California, set up and operated receivers at these two naval stations, equipped with a wire-telegraph circuit to report back to Arlington. On Sunday, 4 July, 1915, Carty and Jewett, confident of immediate success, wished to make the first transcontinental speaking tests themselves, even though atmospheric conditions were at their worst and they were running on less than half power. Carty went through an elaborate series of speech tests moving progressively further away from the microphone without waiting to hear whether Hartley was getting anything at all. Arnold, well aware that only the maximum degree of modulation would stand a chance of getting through, followed Carty's antics by increasing the audio gain every time the microphone output decreased. In spite of Arnold's well-intended intervention their signals were not very intelligible, and Carty was not pleased with Arnold for compromising the integrity of his tests. It was not a very good independence day for either of them.

Tubes continued to blow and each time this happened they tripped the Navy circuit breaker. Worse still, some of the trips were so serious that they produced pitting on the generator commutator. The Navy maintenance men were incensed and they were obliged to add resistance to the feeder cable to limit the short-circuit currents.

The noise made when a tube imploded was considerably enhanced by the glass shards cascading down over tubes beneath it and coming to rest only after hitting the fan blades at the bottom of the rack.

Replacement tubes continued to arrive in a steady stream from New York, but the failure rate made sure that the total in service did not increase rapidly. In the meantime they busied themselves with checks and improvements. The antenna resistance was found to be 2 ohms, and calculations revealed that sidebands beyond one kHz were being seriously attenuated. By increasing the antenna coupling the speech quality improved, at the expense of reduced antenna current.

Convinced that the tests would be successful, orders had been given to manufacture an additional set of racks holding 300 power tubes which could be used at the distant end to permit both-way operation. The layout and construction of these new racks differed from those already delivered to Arlington. All six were designed to stand together as a suite with interconnections and cooling ducts installed in the workshop.

As it became clear that success would depend on having much more power, this suite of racks was diverted to Arlington and squeezed into the little remaining space. When these were connected to the two existing bays the usual problem of "singing" returned, and it took a week to find connections which would defeat the problem. Power tubes continued to arrive in a steady stream and the number in operation rose to about 550. With this many in service there were several tubes failures each day,



Figure 19. *B. B. Webb had the best voice and did most of the talking through the high quality microphone. Note the phonograph on the left.*

and the rate of arrival of new tubes only just kept up with the losses - full capacity was therefore never reached.

Successful Demonstrations

Radio-telephone transmission from Arlington to the large U.S. Navy antenna at Mare Island, 2,500 miles distant, was formally demonstrated on 29 September with Arnold and Hartley operating the equipment. Carty arranged for Cmdr. G.C. Sweet and Lt. Kenshit of the Navy, and A.H. Babcock, consulting engineer of the Southern Pacific Railroad, to witness the tests. A telephone line between Vail's New York apartment and Arlington made it possible for him to speak to Carty via the radio link, whilst the return signal was carried by long-distance telephone. At New York the line from Mare Island was extended to Vail's apartment, and also to Arlington, so that a party of guests gathered there could follow both sides of the conversation. Vail and a group of senior company officials spoke from his apartment while Capt. Bullard, Col. Reber, Cmdr. Hooper, Lt. Coffman, Lt. Bastedo and Cmdr. Bryant observed the tests at Arlington. The demonstration was successful, but as Espenschied pointed out, they had been careful to choose the best time of day.

Figure 20. *H. W. Everitt playing the cornet over the Arlington transmitter.*



A special high-quality microphone was used during the tests (Figs. 19 and 20). Musical frequencies were supplied by a phonograph using an electrical pickup, and by H.W. Everitt, who played his cornet over the air.

The following evening a test to Pearl Harbor Naval Station, near Honolulu, scheduled so that conditions would be at their best, was successfully completed. This was actually the greatest distance (4,900 miles) to be spanned during the whole series of tests and Espenschied, who manned the equipment, was able to cable details not only of the words spoken but also named the speakers (John Mills and Heising). This was achieved in spite of the fact that they had to use a small temporary antenna strung between a smoke stack and a water tank because, for some reason, the regular antenna at the station was not suitable.

Heising recalls the reaction of the Commanding Officer at Pearl Harbor when he eventually came to listen to a telephony transmission from Arlington:

"The Commanding Officer had been as skeptical as Capt. Bullard of our securing any results in the proposed tests, and so had given no attention to Espenschied's work during the months previous. He was still skeptical when he listened to the demonstration. The speech was sufficiently clear to enable much to be understood and speakers' voices recognized. Espenschied reported the incident as follows: The admiral was given a pair of phones and told that the speech to be heard therein was coming from the transmitter at Arlington. He seemed to pay little attention but put on the phones. The speech must have surprised him. He stopped and asked Espenschied, 'Where did you say the signals were coming from?' 'From Arlington,' Espenschied replied. He listened a few moments again, and then turned to his aide. 'Where are the signals coming from?' 'From Arlington,' replied the aide. He listened a few seconds more, then laid down the phones, turned around and walked out without a word. Espenschied felt he didn't believe a word that was told him. Later Espenschied found out from the aide that the Admiral quizzed him further as to how he knew the signals were from Arlington. Subsequently the cabled reports from the U.S. were published in the newspapers, convincing the Admiral that he was not the mere victim of a hoax, so he added his confirmation to those previously made." (2)

The Receiving Station at the Eiffel Tower (Paris)

Attention then turned to reaching Paris from Arlington (3,800 miles). France was in the thick of World War I, and the Eiffel tower (1,000 ft high) antenna was in constant use for monitoring enemy transmissions. The war was still in a critical phase - only twelve months previously.

"...the Germans had been near the outskirts of Paris and were stopped only by rushing reinforcements in a fleet of Paris taxicabs." (4)

According to H.E. Shreeve ,

"At night, for instance, from the top of the Eiffel Tower, the flash of the guns on the firing line is plainly visible." (5)

The French Government was approached and, even though the tests would be of no help to their war effort, they agreed to provide accommodation for the equipment and to make the antenna available for short periods. Lt. Cmdr. Ferrié, Capt. Brenot, Capt. Pincimin, Lt. Valbreuze and several officers of the French Radio Telegraph Service showed a great deal of interest in the project and made the necessary arrangements. H.E. Shreeve and A.M. Curtis had traveled to Paris to install and operate the receiving equipment. Towards the end of September, 1915 the antenna was made available for tests for about ten minutes at some time between 5:00 a.m. and 5:30 a.m.

Initially a transmission frequency of about 50 kHz was used, but it was almost impossible to hear a weak signal in the face of several powerful European telegraphy stations transmitting on nearby frequencies. The cable link between Europe and the U.S. was monopolized by military needs, but eventually they were able to rearrange the program so that alternative frequencies of 40 kHz and 60 kHz could be tried.

The change of frequency did the trick, and between 12 and 20 October snatches of speech came through. But it was not until 21 October that Shreeve and Curtis and a few French observers heard B.B. Webb in Arlington say, *"Hello, Shreeve"* several times and finally, *"And now, Shreeve, good night."* On 23 October a formal demonstration was arranged for senior officials, including Cmdr. Sayles (Naval Attaché to the American Embassy) and several French Army representatives.

The Atlantic had been crossed and the point made that it was possible to speak to Europe, so Shreeve and Curtis packed their bags and returned home. Heising's reports as follows:

"The news of the radio tests created quite a stir in the country. Most every radio amateur in the country must have tuned in to hear us. I believe many were disappointed as we published no schedule of time or wavelength although we continued our tests to reach Paris" (2).

Lee deForest Takes an Interest in the Tests

Lee de Forest also read the press reports and to quote Heising,

"Dr. de Forest was probably the individual who was most deeply stirred by the news. He rushed into print quickly to secure all the publicity he could get out of it and talked as though he knew all important details of the apparatus. However, he must have felt that he needed more information because he suddenly showed up at Arlington to try and pump Capt. Bullard. Dr. de Forest arrived there just as we were all sitting down to lunch. All summer we ate lunch at midday at the officer's mess in the Naval Building. Capt. Bullard always sat at the head of the table. When de Forest arrived Bullard invited him to have lunch with us, and he accepted. All of us were introduced, but as far as his interests were concerned, we might as well have been posts. Bullard had only mentioned our names, and he supposed we were all Naval people. De Forest immediately began to try and pump Bullard as to our apparatus. He asked question after question which Bullard either parried or said he didn't know. Finally Bullard told him that if he wanted information about the apparatus he should ask the telephone company representatives, and called his attention to Webb, Everitt and myself at the table. De Forest turned his head quickly and looked at us for some seconds with astonishment, just as though we had mysteriously appeared at the table from nowhere. He said nothing, however, but dropped all talk of the subject with Bullard.

"De Forest apparently noticed that our tests were continuing and he conceived the brilliant idea of going to Europe and listening to our signals over there, and then get all the publicity he could out of it. Our people got wind of it when he sailed, and got further word of his sudden arrival in Paris. Before he could make arrangements to listen to us, however, we succeeded in completing our tests and stopped our transmissions. A.M. Curtis has an interesting story of de Forest's efforts to get permission to listen in Paris and of the suspicion of the French that he was some spy. Before throwing him in jail, however, they asked Shreeve if our people knew him. Upon Shreeve explaining de Forest's interest in our tests they were satisfied as to the cause of his suspicious behavior, and did not molest him. De Forest to this day doesn't know how near he came to going into the calaboose."



Figure 21. 1925 photo of Arlington group: Rear: W. Wilson, R.A. Heising, R.V.L. Hartley, J. Mills, H.W. Everitt. Seated: B.B. Webb, H.E. Shreeve, H.D. Arnold, R.H. Wilson. Inserts: Left: L. Espenschied, Right: E.H. Colpitts.

The Problem of Changing Transmission Frequency

Before success in crossing the Atlantic could be achieved several changes of transmission frequency were required. Heising makes the following observations about the process:

"The shifting of wavelength was none too easy to handle with the type of circuit we had. First the oscillator frequency was changed to a calibrated point. Then the output circuit from the modulator was retuned. Then the antenna coil was connected to a different tap. Then the resistance elements in the output circuit from the amplifier were readjusted so the power tubes didn't sing. Then the oscillator was readjusted slightly to the resonant antenna frequency; then all intermediate tuned circuits were readjusted as well as antenna coupling, and finally the coupling for adjusting the voltage on the modulator from the oscillator was changed. Then we were ready to apply increasing plate voltages up to full voltage with maximum power adjustment on the modulator, which if correct allowed us to switch to talking adjustment and begin to send signals." This process took at least twenty minutes.

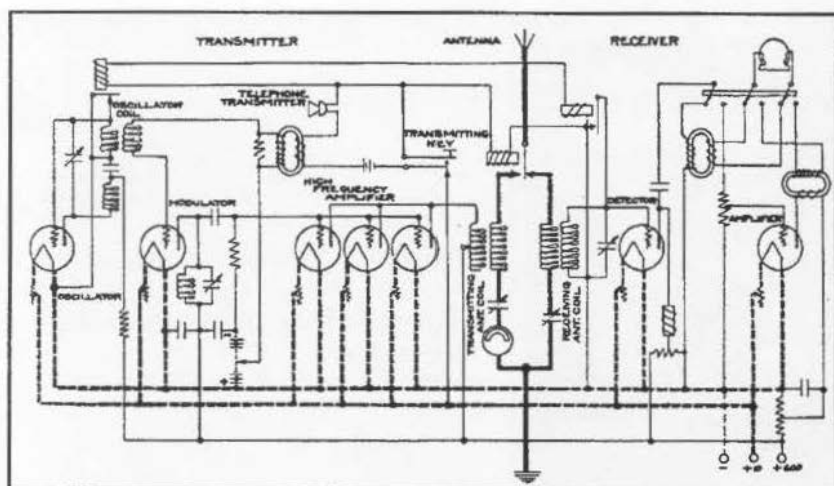


Figure 22. Battleship set made in December, 1915. (1)

Heising states that each tube delivered only four watts (unmodulated) which rose to a peak power of fifteen watts when fully modulated. With 550 tubes in operation, the Arlington transmitter would therefore have delivered about 2.2 kW unmodulated, and about three kW fully modulated.

After the Paris tests several demonstrations were arranged, and Carty gave a dinner in New York to celebrate his election to the Lotus Club, at which he provided each guest with a pair of headphones so that they could listen to a radio-telephone message sent from Arlington. Those engineers not required to operate the equipment were invited to the dinner and were as much impressed with their first acquaintance with Champagne as the official guests were with the demonstration.

First Fruits of the Tests

Several demonstrations were given to Army and Navy top brass. Secretary of the Navy Daniels asked for a two-way telephony demonstration with a ship at sea. A low-powered transmitter and a receiver were constructed and installed on the *U.S.S. New Hampshire*, which in conjunction with Arlington and a land-based receiver at Norfolk, VA, provided a full telephone link between Secretary Daniels and Capt. Chandler while the *New Hampshire* was in Hampton Roads. Telephone lines were then used to extend the link to the Great Lakes Naval Station and then to Mare Island, so that the Commandant, Capt. F.M. Bennett, could converse directly with Capt. Chandler, with the ship up to fifty miles from Norfolk. The equipment on the *New Hampshire* was located on the lower deck, with the telephone transmitter and receiver installed on the bridge.

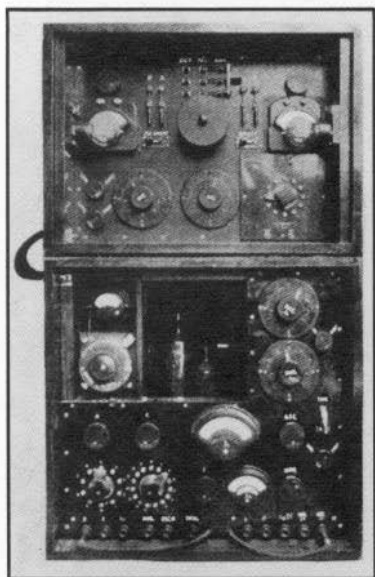


Figure 23. Battleship transceiver (1915) — note the shorter tube (type S?) alongside the type-W tube inside the transmitter.

Commander Hooper of the Bureau of Steam Engineering then asked Western Electric to provide two experimental sets for installation on battleships, to give his staff an opportunity to evaluate radio telephony from an operating point of view. The circuit diagram for these two sets is shown in Fig. 22. The wavelength could be set between 600 & 1200 meters (250-500 kHz). The low-power transmitter produced about one ampere in the antenna. This was sufficient to cover the prescribed range of thirty miles, and in practice they were heard up to 175 miles away. Sets were installed on the battleships *Arkansas* and *Florida* at Guantanamo, Cuba, early in February, 1916 (Fig. 23). This is the only illustration which shows a short version (presumably type S) of the type-W tube.

The main problem encountered was interference from existing telegraphy equipment, and it was decided to move to much shorter wavelengths so that they could completely separate wireless telephony from telegraphy. A few field experiments were made, with short-wave antennas on two ships, in July 1916, and a new design study was started in October.

Heising devised a system of multiplexing in which the transmitted carrier could be modulated with a speech sub-carrier of either 25, 35 or 45 kHz. The intention was to allow up to three ships in the same neighborhood to send on the same carrier frequency, provided each used a different sub-carrier. In addition, a choice of three carrier frequencies was available with wavelengths of 150, 189 and 238 meters (about 2, 1.59 & 1.26 Mhz). It was intended that equipment could be operated simultaneously by up to nine ships in the same area without mutual interference. Simplified diagrams of the transmitter and receiver are reproduced in Figs. 24 and 25. Sets were installed on the *U.S.S. Pennsylvania*, *Wyoming* and *Seattle*

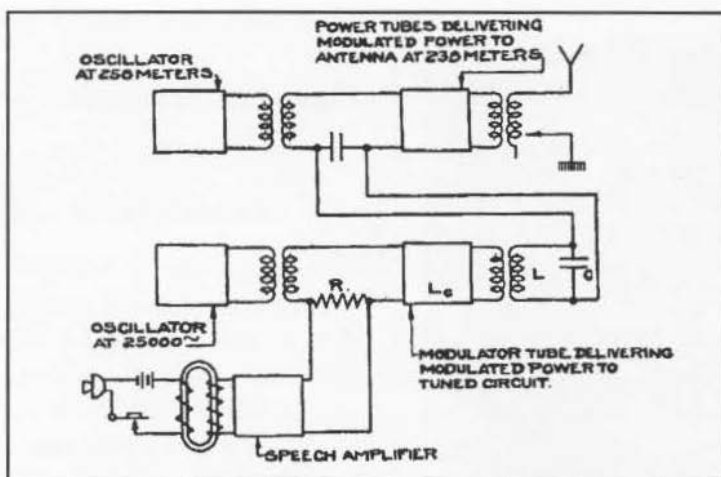


Figure 24. Simplified diagram of a multiplex transmitter.

in January, 1917. Soon afterwards, however, diplomatic relations with Germany were severed (3 February, 1917) and the Navy was no longer available for tests. It appears that this was the first practical application of the "carrier" principle. The author has no further information about these sets (illustrated in Fig. 26) and would be interested to know whether they were successful and whether any similar system was ever used in the field.

President Wilson ordered the arming of American merchant ships so that they could defend themselves against U-boat attacks, and on 6 April, 1917 the U.S. declared war on Germany. In March the Navy requested fifteen experimental sets for use on submarine chasers. These were essentially C.W. telegraphy sets, but they also carried a telephony attachment. Four type-W tubes were used in the output stage, delivering 1.5 amperes to the small antenna on the 110-foot vessels. These sets were replaced soon afterwards by equipment which will be described later.

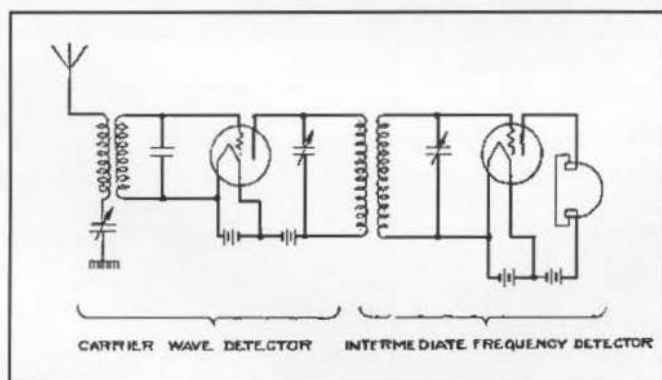


Figure 25. The receiver used for U.S. Navy multiplexed signals (1).

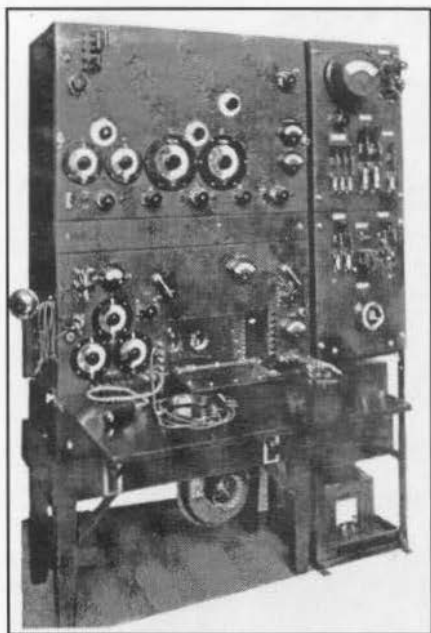


Figure 26. *A multiplex transceiver for the Navy.*

Aircraft Telephony

American aviation was still in its infancy when the U.S. entered World War I. The army had a small air-force unit, under the control of the Signal Corps, which consisted of 65 officers and 1,087 men but not a single combat aircraft. The Naval air arm had 38 aviators, 160 enlisted men and possibly a dozen hydro-airplanes based at Pensacola, but none of these carried armaments.

(6) Wireless telegraphy using spark equipment had been tested between air and ground (an example of a British test is shown in Fig. 27) but was hardly suitable for use in combat.

In these circumstances someone at A.T. &T. must have had remarkable foresight to start experimenting with radio telephony for use in aircraft. H.W. Nichols was appointed to direct the work and A.T. &T. developed a short-range experimental set. This was successfully demonstrated but was not acceptable because of its weight (Fig. 28).

A meeting was held in Major General Squier's office (Chief Signal Officer of the Army) in Washington on 22 May, 1917, attended by Col. Rees of the Royal Flying Corps of Great Britain and Capt. C.C. Culver of the Signal Corps with Major F.B. Jewett and Major E.B. Craft of the Western Electric Company. As a result of this meeting the company was ordered to proceed with the development of a radio-communication system to

Figure 27. *A British "Flanders" monoplane equipped with wireless telegraphy before 1914. (16)*



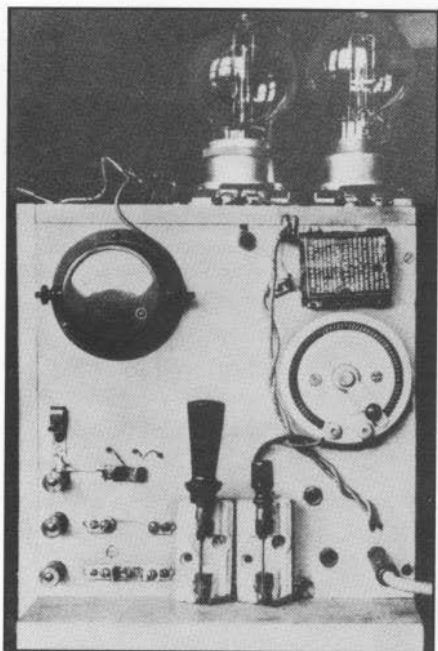


Figure 28. *Prototype used in early aircraft radio tests.*

provide reliable short-range communication between aircraft.

Within six weeks a telephony link with flying aircraft was demonstrated, followed soon after by successful communication between planes in the air as well as with the ground.

But serious problems arising from the difficult environment encountered in the flying machine had still to be solved. The noise from the engine combined with the rush of air in the open cockpit did not make it easy to hear voice signals, nor was it a

favorable background for reproducing speech.

The padded leather flying helmet incorporating the headphones started life here and solved the audibility problem (Fig. 29). The speaking difficulty was tackled thus: "A brilliant line of experimentation, largely at the hands of J.P.Minton of the Transmission Laboratory, resulted in a form of a telephone transmitter or microphone, which possessed the remarkable quality of being insensitive to engine and wind noises, and at the same time very responsive to the tones of the voice." (7)

The team had to ensure that the equipment could withstand severe jolts and vibrations without adding excessively to the weight, as those early aircraft had a limited carrying capacity. Batteries would have been the most convenient form of power supply but had to be rejected because of their weight. They were not permitted to couple



Figure 29. *Observer equipped with telephone equipment.*



Figure 30. *Wind-driven generator to power radio equipment, fitted to a Curtiss J.N. "Jenny" trainer.*

generators directly to the engine, and finally solved the power-supply problem by using a 100-watt outboard wind-driven generator (Fig. 30). The airspeed could vary from forty to 160 miles per hour and the corresponding generator speed ranged between 4,000 and 14,000 RPM. H.M. Stoller devised a regulator circuit exploiting the rapid change of diode anode current with increasing filament voltage (Figs. 31 and 32). The rotor had separate windings and commutators for the high-tension and the low-tension supplies. Two field windings were provided; the main coil was fed via the regulator-diode filament from the low-voltage supply, and the current for the second differential coil depended on the anode current passing through the diode. As the speed of the generator rose the diode-filament current increased until the filament reached its normal operating temperature. The diode-anode current then rose rapidly and produced an opposing flux in the differential field which minimized any further changes in output. This must surely be the first electronic control circuit!

Figure 31. *Voltage regulation of wind-driven generator.*

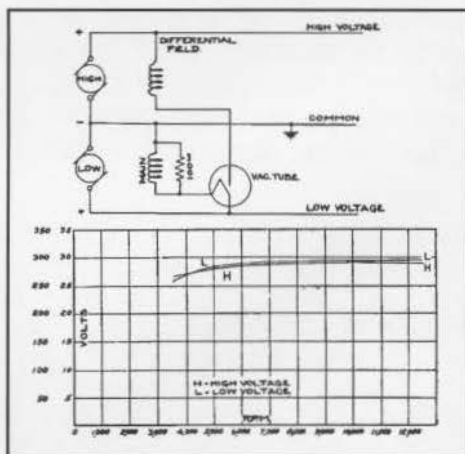
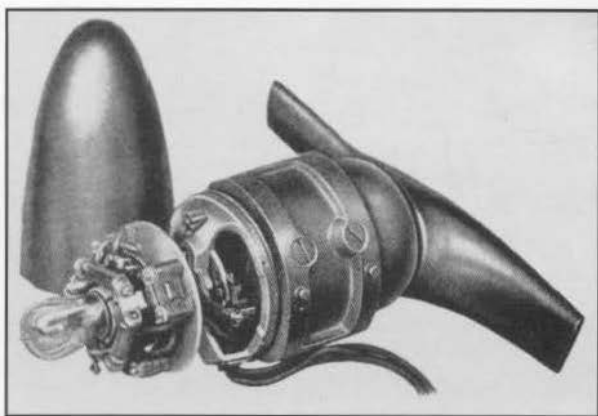


Figure 32. Wind-driven generator (Kenotron TB1), showing voltage-regulating tube.



The antenna consisted of a 200-foot trailing wire, terminated in a lead weight which could be reeled in or out as required. This appendage was acceptable when flying alone but was embarrassing when flying in the presence of other aircraft. Ignition interference had to be eliminated by using screened high-tension cables.

Finally on 2 December, 1917 the equipment was demonstrated to the Aircraft Production Board and the joint Army and Navy Technical Boards at Moraine Flying Field in Dayton, Ohio. This crucial test was described as follows:

"The planes left the ground and after what seemed to be an interminable length of time, we got the first sounds in the receiver, which indicated that they were ready to perform. The spectators were only mildly interested, and some seemed to be a bit bored. Suddenly out of the horn of the loud speaker come the words, 'Hello, ground station. This is plane No. 1 speaking. Do you get me all right?' The bored expression immediately faded, and looks of amazement come over their faces. Soon we got the same signal from No. 2, and the show was on. Under command from the ground the planes were maneuvered all over that part of the country. They were sent on scouting expeditions and reported what they saw as they traveled through the air. Continuous conversation was carried on, even when the planes were out of sight, and finally upon command they came flying back out of space and landed as directed. (7)

"From that moment the radiotelephone was sold. It was not a question after that as to whether it would work or was any good, but how soon could we start manufacture and in what quantity."

Before the first SCR-68 transceivers could be delivered early in 1918, an exhaustive process of evolution and testing had to be endured. A total

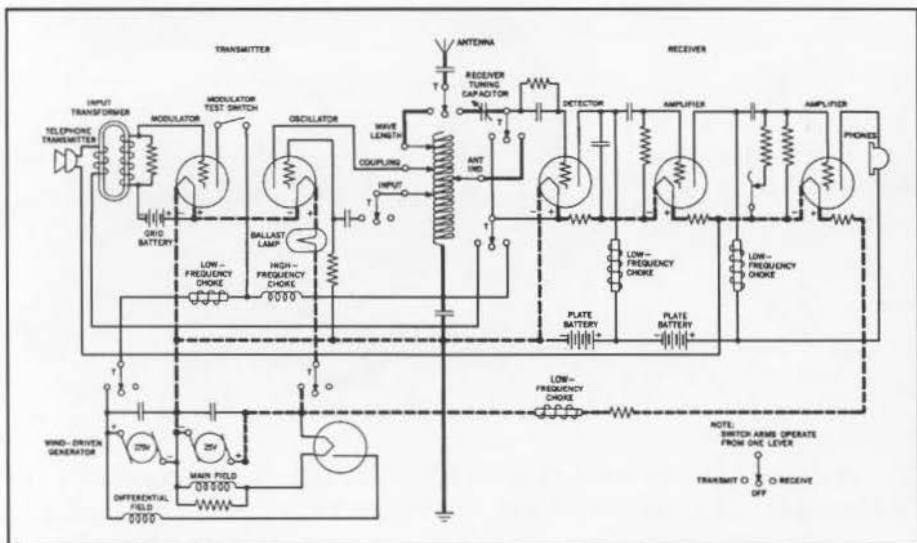


Figure 33. Circuit diagram of the complete SCR-68 transceiver.

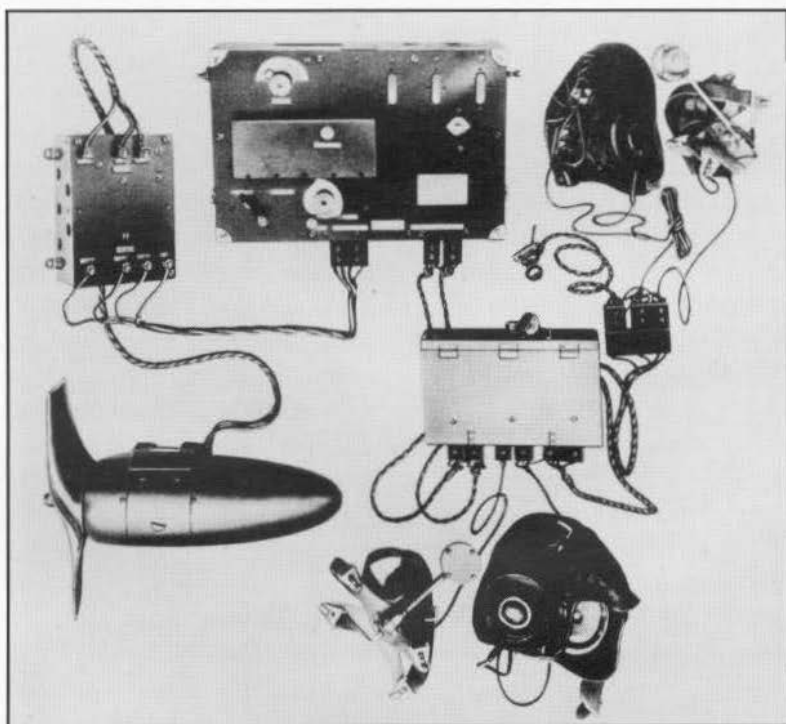


Figure 34. Complete set of equipment (SCR-68) for a two-place airplane.

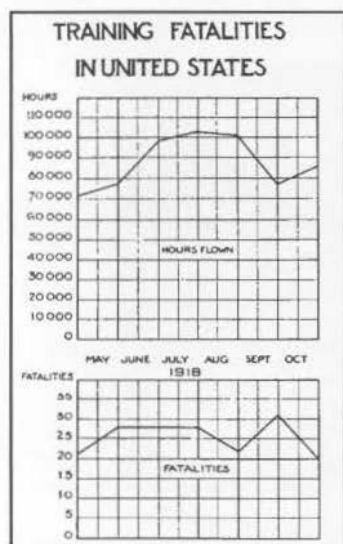


Figure 35. Training fatalities in United States.

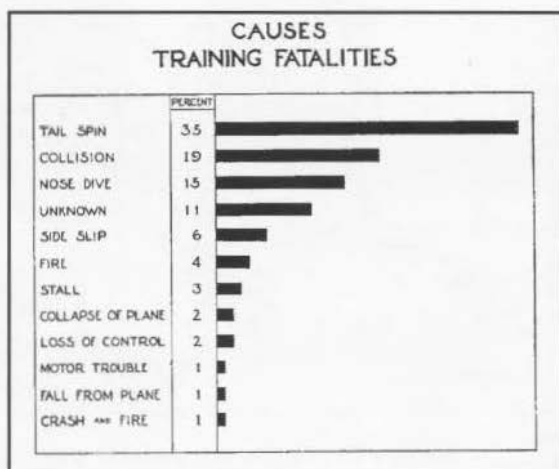


Figure 36. Causes of training fatalities.

of 690 test flights were required. A.A. Oswald alone made 302 flights, clocking up 484 flying hours, and lived to tell the tale. As E.B. Craft put it,

"It is a truly remarkable and happy fact that during all this flying, not one serious accident was recorded. It is no use talking about the narrow escapes, for in this game also, a miss is as good as a mile" (7).

Major General Squires' gives statistics on training during World War I (Figs. 35 & 36) and comments,

"It will be seen that our training casualties have been astonishingly few. Statistics show that the U.S. has a lower percentage of fatalities than any of the other allied countries. The monthly average has been only one fatality for each 3,200 hours flown" (8).

The equipment delivered five watts in the frequency range 600-1500 kHz (see Fig. 33 for circuit diagram). By this time Heising had perfected the class-C amplifier and his constant-current modulator which together produced a more effective and efficient transmitter. VT-2 tubes were used for both the modulator and the power oscillator. The receiver had a grid-leak detector followed by two stages of audio amplification using

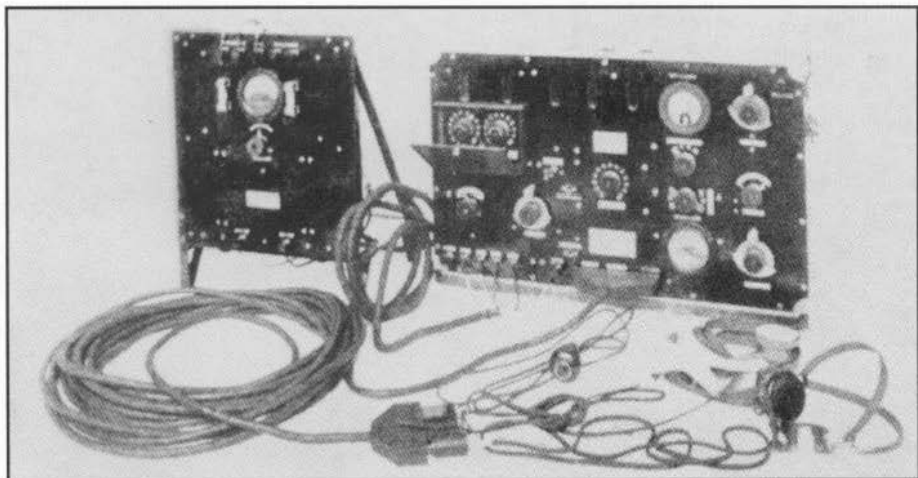


Figure 37. *Radio-transceiver ground station (SCR-67).*

VT-1 tubes. Two sets of microphones and headphones were provided for intercommunication between the fore and aft cockpits in addition to serving the radio function. The intercommunication capability was an important advantage, as previously the only means of conveying information between the pilot and his passenger was by hand signals. All together the equipment weighed 58 lb.

The original requirement was for reliable communication for distances up to 2,000 yards, but in practice it was possible to communicate between planes up to 23 miles apart and 45 miles from the ground station.

Fig. 37 shows a variation of the transceiver (SCR-67) primarily intended for use on the ground by training instructors wishing to send comments and instructions to pupils in the air. By the end of the war many thousands of these sets had been manufactured and installed in aircraft in the U.S. and in Europe.

The whole emphasis in designing this equipment had been on the need for quick results, and little time was allowed to determine optimum choices. This was especially true of the low operating frequency requiring a long trailing antenna which could be hazardous in combat or close flying formations. Before the end of the war further work was done between 2-4 MHz with shorter antennae. Fig. 38 shows the resulting equipment which was split up into smaller modules to make it easier to accommodate in confined spaces. Antenna wires extending from the wing tips to the tail were tried, but although this was better aeronautically it did not have good radiation characteristics. The best solution used two short antennae trailing from the wing tips and joined across the wing with the airframe as a counterpoise. Fig. 39 compares the radiation patterns for the original single long wire with that of the double antenna.

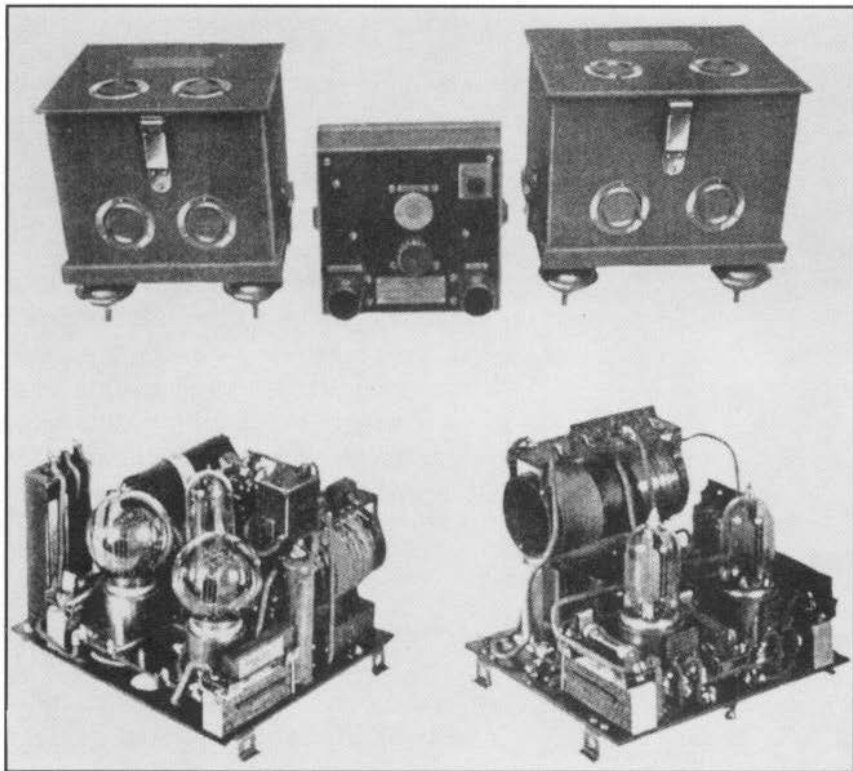


Figure 38. *Short-wave version which was developed later.*

Submarine Chaser Radio

The aircraft radio was so successful that the Navy decided to use similar equipment on their small 110-foot vessels for chasing enemy submarines. The CW-936 transceiver provided two-way communication between commanding officers aboard vessels involved in a chase. A hand-held microphone and either headphones or a loudspeaker was provided in the pilot house. Any one of five wavelengths (250-600 meters) were available to provide selective calling. Several thousand of these sets were installed in chasers stationed mainly in Europe — Figs. 40 and 41 shows the transmitting and receiving units.

Postwar Developments

The pace of radio-telephony development slowed down abruptly after 1918. Some attempts were made to provide a telephone service to ships at sea and a few point-to-point radiotelephone links were established,

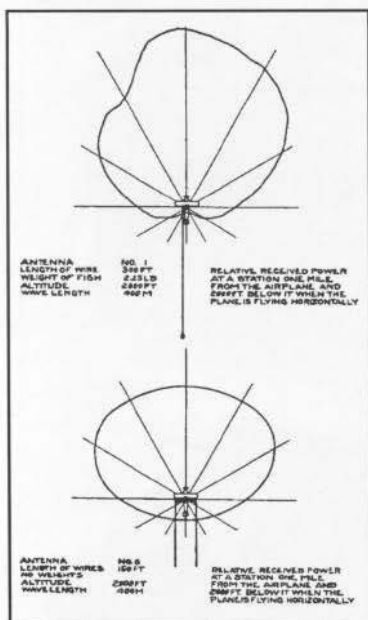


Figure 39. Directional characteristics of trailing-wire antennae.

but these were discouraged by the postwar slump. Telephony required more bandwidth than telegraphy and with the demand for air space growing rapidly the need for lone frequency allocations became increasingly urgent. Until international agreements were reached no one wanted to spend money on developing new systems.

Before a regular transatlantic-telephone service could be implemented much more spade work had to be completed. Telegraphy over the same distance had been operating for some time using

wavelengths below 30 kHz; these had dependable characteristics but were not suitable for telephony. When conditions deteriorated a telegraph operator could ask for a spoiled message to be repeated, and if necessary traffic could be held up until conditions improved. Telephony users would not tolerate such compromises and a much more consistent path was required.

The obvious way to improve the signal-to-noise ratio was to increase the transmitted power, but this had to be achieved with far fewer tubes than were required at Arlington. W. Housekeeper of Western Electric

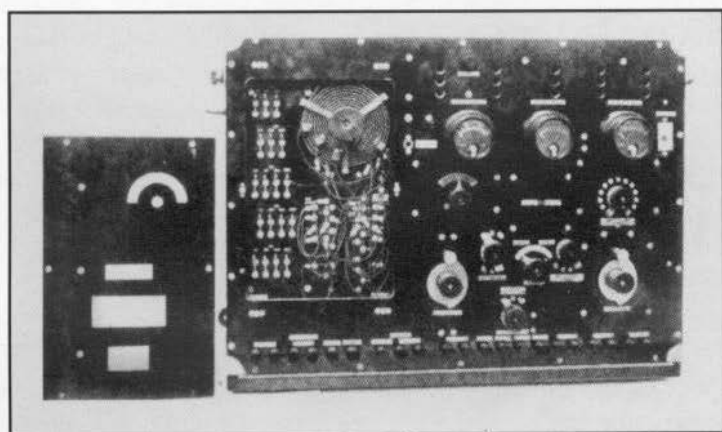


Figure 40. Submarine chaser Transceiver CW-936.

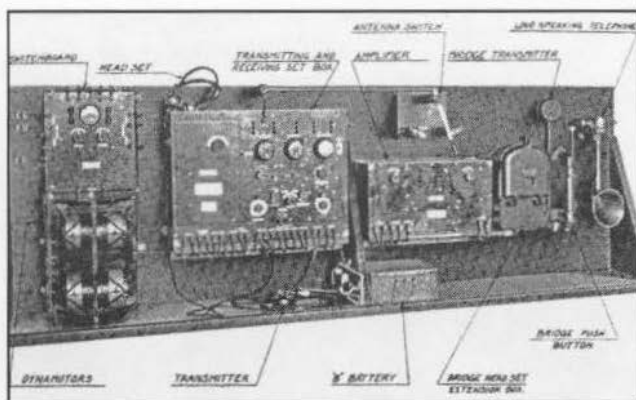


Figure 41. A complete assemblage of the CW-936 submarine chaser radio-telephone equipment with its accessories.

developed a new glass-to-metal seal in 1919 which allowed the metal anode to become part of the sealed tube envelope. Now, instead of being enclosed within a glass tube, the anode could be exposed directly to the cooling medium, and transmitting tubes capable of dissipating ten kW and more could be made (Fig. 42).

In 1915 J.R. Carson at Western Electric developed single-sideband modulation for use in wire transmission, and it was quickly realized that this could convey intelligence much more efficiently than simple amplitude modulation.

Studies revealed that most atmospheric noise originated in the tropics. By locating a receiver as far north as possible and by using a directional antenna the signal-to-noise ratio could be improved significantly.

In 1923 all of these improvements were brought together for a test on 60 kHz, using the large RCA antenna at Rocky Point, Long Island, to transmit to a big loop antenna in England. This time speech of consistent commercial quality came through, and this led the way to a two-way telephone link which was put into regular service in January, 1927.

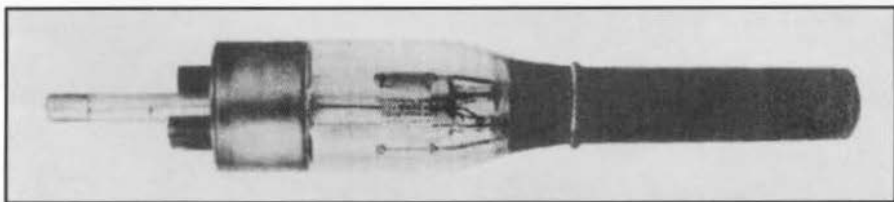


Figure 42. Western Electric 10-kW water-cooled transmitting tube type 220B (ca 1921). The glass-to-metal union was made using the Housekeeper seal.

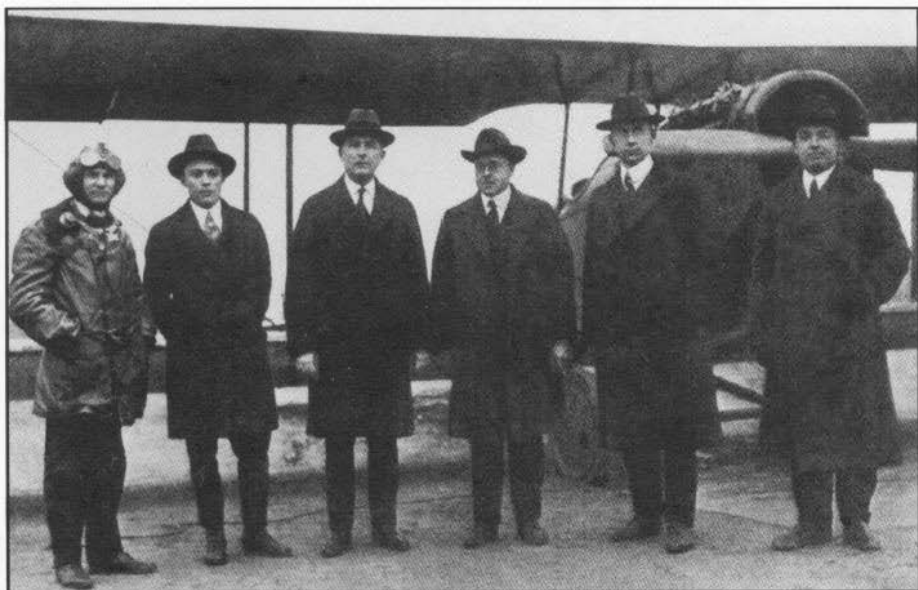


Figure 43. *The team that did most of the field work on the airplane radio telephone. Left to right: J.P. Minton, R. Guenther, E.B. Craft, L.M. Clement, R.A. Heising and A.A. Oswald.*

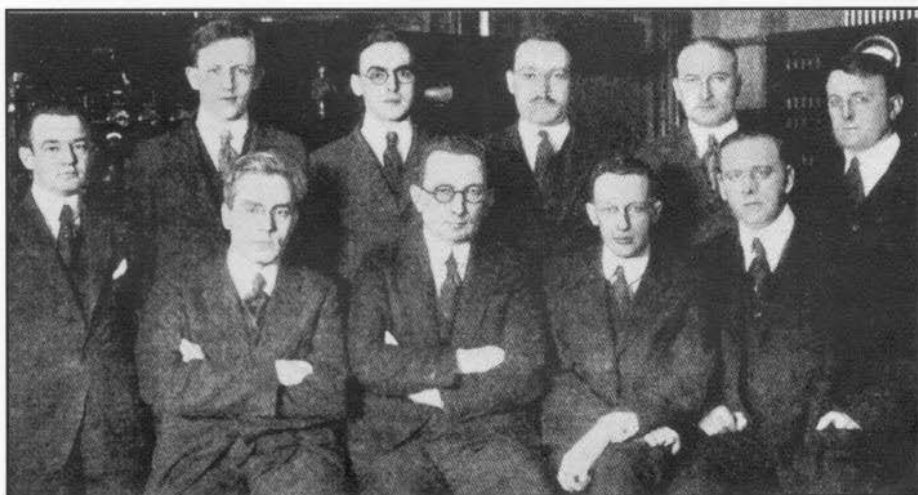


Figure 44. *Part of the research and design team on the radio-telephony projects. Standing (left to right): W.A. Boyd, E. Wilson, W.E. Booth, H.M. Stoller, C.S. Winston, G.H. Stephenson; Seated: H.J. van der Bijl, J.J. Lyng, H.W. Nichols, W.T. Booth.*

WASHINGTON.

December 9, 1918.

My dear Mr. Vail:

The Chief Signal Officer, General Squier, has called to my attention the splendid spirit of cooperation and helpfulness which has been evinced during the war by the wonderful engineering organization of the American Telephone and Telegraph Company. The Airplane Radio Telephone Set, which has proven so satisfactory to the Air Service, and which has brought about entirely new methods of military use of airplanes, is a particular example of the result of this cooperation. The evolution and development of this and other important apparatus was made possible only because your engineering staff freely furnished the highly technical knowledge and skill necessary in the development, design and manufacture of the sets.

Please express to your engineers my appreciation of the splendid service rendered.

Very truly yours,



Secretary of War.

Mr. Theodore N. Vail, President,
American Telephone and Telegraph Company,

Figure 45. Letter of commendation from Newton D. Baker, Secretary of War.

The promise of the Arlington tests had at last been realized and the "Grand System" of Alexander Graham Bell, in which any person would be able to talk to anyone anywhere in the world, was another step closer.

Craft and Colpitts, in their paper published in February, 1919, took a glimpse into the immediate future and predicted that radio telephony would prosper in three main areas:

".... These stations (radio) will be of two kinds: Moving, such as ships, airplanes, trains, trucks; and fixed but inaccessible, such as on islands, in deserts and in very sparsely settled regions.

"A third class of service is that which is concerned, not with single individuals, but with groups; such as the broadcasting of news, time and weather signals, and warnings. In some cases one objection to radio telephony would be an advantage in this class of service."

Western Electric moved into this third class of service shortly afterwards and produced hundreds of radio broadcasting transmitters which found their way all over the world, including Johannesburg, South Africa.

It is rare to find a chain of events that remained so consistently favorable. Carty's determination to proceed with the Arlington tests, which could hardly have been expected to return immediate benefits, led to the participation of the Navy through the use of their Arlington facilities. This in turn

Dear Hendrick,

The old radio
crowd are having
a dinner in commem-
oration of the 25th
anniversary of the
transmission of the
voice across the
atlantic. We wish
you were here with
us

Arthur V. Kendall
B. B. Webb
H. W. Everett

R. A. Heising
Austin C. Miller
Oliver E. Buckley
Howard A. Starnhart
R. H. Wilson

Carl R. Englund
Lloyd Spunkard
Robert E. Mann
Edwin H. Colpitts
Frank B. Smith
Ralph V. L. Hartley
H. Wilson

Figure 46. Copy of letter sent to Dr. H. J. van der Bijl in 1940 at the dinner commemorating the 25th anniversary of the Arlington radio-telephony tests.

meant that the tests were familiar to the very people who would require telephony equipment when war broke out. By looking ahead and seeing the value of radio telephony in aircraft, Western Electric jumped several steps ahead of their competitors and were ready to show that they could provide equipment when it was most wanted. Under Vail the company had introduced some of the finest research facilities in the world, and these had ensured that their technology advanced sufficiently to keep them foremost in the business. The cost had been considerable, and the company's earnings had suffered, but the dividend came in the form of dependable growth.

Some of the conclusions to Heising's report on the tests were as follows:

"The consensus of opinion of those of us who worked at Arlington was that there probably would never be another transmitter like it Aside from technical matters, the experience at Arlington stands out so that it will always be remembered. It is one of the things I can always look back to with pleasure. It is one of the landmarks in my life, or expressed another way, is an event to reckon time from, and the latter I do very often."

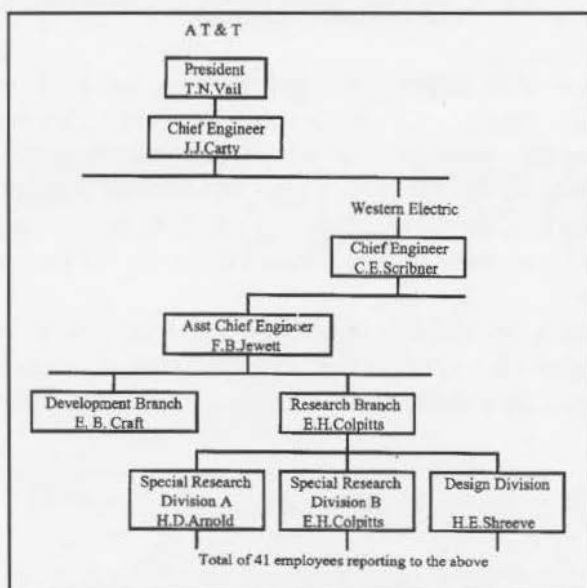


Figure 47. Part of the organization chart in 1915 of the Western Electric Engineering Dept.

On 21 October, 1940 fifteen of the original team of engineers involved in the Arlington tests assembled at the Bell Telephone Laboratories, 25 years after the first successful radio-telephone reception in Paris. It would have been appropriate to have reenacted the achievement by speaking over the telephone to someone in Paris, but by this time World War II had intervened, and instead Dr. F.B. Jewett spoke to A.A. Scott, the president of the Mutual Telephone Company in Honolulu. To quote from the New York Times report of the occasion:

"As they took turns in participating in the call, more than one was heard to remark that the connection was 'as good as a local call' and that it was a marked contrast to the weak tones received, in 1915, from the Arlington radio station of the United States Navy amid crashing static."

H.E. Shreeve commented that after repeated failures he and his partner were disconcertingly dubbed "*Yankee bluffers*," and it was with "*relief in justification*" that they finally picked up the Arlington call clearly. Afterwards they attended a dinner at the University Club, and to quote again from the newspaper,

"A participant in the 1915 tests unable to attend was Dr. H.J. van der Bijl, now Director General of War Supplies for the Union of South Africa."

Fig. 46 shows the note sent to him signed by those present.

Acknowledgements:

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He would like to pay special tribute to his wife, Irene, for her encouragement and help throughout the long period of preparation. It was she who taught him most of what he knows about writing through her patient editing of his drafts.

Illustrations

The following illustrations are the property of the A.T. & T. Archives and are reprinted with the permission of A.T. & T.: Figs. 2, 4, 6-21, 28-34, 38, 39, 42-45. Unfortunately most of the pictures relating to R.A. Heising's notes (ref. 2) had to be reproduced from Xerox copies of the originals (made in 1984) resulting in a loss in quality.

APPENDIX -

Further information on some of the key figures :

Theodore N. Vail

Born 16 July, 1845, Minerva, Ohio Died 16 April, 1920, Baltimore

His successful career in the Railway Mail Service culminated in his appointment as general superintendent in 1876. The Bell Telephone Co. persuaded him to take on the job of general manager in 1878. He was made president of A.T. & T. from 1885 until 1887 and again from 1907 until he retired in 1919. Although he had no technical training he had a nose for the right projects to back, and had a significant influence on the growth of the company.

John J. Carty

Born 14 April, 1861, Cambridge, Mass Died 27 December, 1932

Started in the New England Telephone and Telegraph Company as a boy telephone operator and rose through the technical ranks. He became

an electrician with the Metropolitan Telephone & Telegraph Co. in 1887 and chief engineer in 1897. In 1907 he was appointed as chief engineer of A. T. & T., and as vice-president in 1919. He was unqualified academically but had a natural talent. In 1881 he demonstrated the superiority of two-wire telephone connections when a single galvanized-iron wire with an earth return was normal. He was awarded many patents, including those on line transposition and a phantom telephone line circuit.

Frank B. Jewett

Born 5 September, 1879, Pasadena, Ca. Died 18 November, 1949

Graduate of Throop Polytechnic in 1898 (now California Institute of Technology). Awarded Ph.D. at Univ. of Chicago in 1902. Taught physics at M.I.T. and then joined A.T. & T. as transmission engineer in 1904. Became vice-president of A.T. & T. in charge of research in 1925, and was president of the Bell Telephone Laboratories from 1925-1940, and then chairman of the board of directors.

Harold DeForest Arnold, Ph.D

Born 3 Sept., 1883 in Woodstock, Conn. Died 10 July, 1933 Summit, NJ

Trained at Wesleyan University, Conn. Post graduate studies at Chicago University under Prof. R.A. Millikan. He joined Western Electric Research Branch in January, 1911. Produced a mercury-vapor discharge-tube amplifier and then headed the team which developed the Audion into a practical amplifier for telephone and radio work. He stimulated fundamental research into speech and hearing which was eventually used to define realistic limits to distortion in sound-reproduction systems. G.W. Elmen and Arnold worked on Permalloy, a magnetic material with exceptionally high permeability which was used in audio transformers and also wrapped in tape form around submarine telegraph cables to provide continuous loading. In 1925 he became director of Research at the start of the of Bell Telephone Laboratories.

(Question: Was Arnold related to Lee de Forest?)

Edwin H. Colpitts (15)

Born 1872 in New Brunswick, Canada.

Died 1949

Graduated from Allison University in 1893. Received his B.A. and M.A. from Harvard in 1896 and 1898. Joined Bell Telephone Co. in Boston in 1899 to work with G.A. Campbell on telephone-line loading coils. In 1907 he became a research engineer with the Western Electric Co. in

N.Y. working on cable and radio-telephone systems. In 1911 he was appointed head of the Research Branch of Western Electric where he had a direct impact on the development of radio telephony. He became Vice President in the Dept. of Development and Research of A.T. & T. in 1924 and was Vice President of the Bell Telephone Labs. from 1934 until he retired in 1937.

Ralph V. Hartley

Graduated from the University of Utah and became a Rhodes scholar. In the mid '20s, following the work of Nyquist at A.T. & T., he published an important paper on information theory which was only overshadowed by Shannon in 1948.

Raymond A Heising

Born 10 August, 1888, Albert Lea, Minn.

Graduated from the University of N. Dakota in 1912 and gained an M.S. degree from the University of Wisconsin in 1914, and then joined the Research Dept. of Western Electric. He was eventually granted 117 patents covering radio circuits, modulation, multiplexing, etc. In addition to the work outlined in the body of this article his early work led to multi-channel carrier-telephone systems. In the '30s he became interested in U.H.F. and piezoelectric phenomena. He was elected president of the IRE in 1939.

Hendrik J. van der Bijl (pronounced fun der bale)

Born 23 November in Pretoria, S. Africa Died 2 December, 1948

He was the 3rd student to receive the degree of BA in Physics from Victoria College (now Stellenbosch University) in 1908. Did his postgraduate studies in Germany at Halle, Leipzig and Dresden. He came to the attention of Prof. A. Millikan of the University of Chicago at a conference in Germany. On Millikan's recommendation, F.B. Jewett offered him a position under Arnold to work on the Audion which he took up in 1913. Most of the mathematical relationships between tube parameters were developed by him and culminated in his book on the vacuum tube. 1920 General Smuts persuaded him to return to S. Africa as a Scientific Advisor to the government. He was largely responsible for starting the Electricity Supply Commission which generated and distributed electricity nationwide, and subsequently the Iron and Steel Corporation which was the first significant industry, apart from gold mining, in the country.

At the start of World War II he was made Director General of War Supplies. Van der Bijl contributed more than anyone else to the development of industry in S. Africa.

Lloyd Espenschied

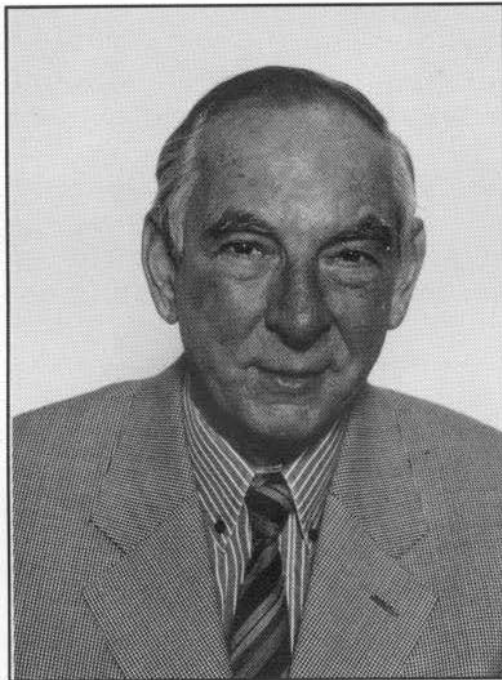
Born 27 April, 1889, St. Louis, MO

Built and operated one of the first amateur wireless stations in 1904 and worked as a wireless telegrapher for the United Wireless Telegraph Co. He graduated from the Pratt Institute in 1909. Joined A.T. & T. in 1910 to work on loading of lines and high-frequency transmission on wires and radio. He became director of high-frequency transmission at the Bell Telephone Laboratories in 1934 and was involved in the development of coaxial-cable systems. He invented a sharp cutoff quartz crystal band-filter for carrier systems, and among his more that 100 patents are an aircraft altimeter and other radio-wave reflection devices. He was awarded the Medal of Honor of the IRE in 1940. After his retirement in 1954 he published a number of papers on the history of electrical technology.

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Dirk was born in 1930 and has spent most of his life in Johannesburg, South Africa. The radio bug bit Dirk in junior school in about 1941. His uide was a chum (Harry Moir, now living in Orlando, FL) whose father had been making radios since the '20s. He gained a BSc in Electrical Engineering (light current) from the University of the Witwatersrand in 1951. He then moved to England for industrial experience at the Automatic Telephone and Electric Co., Liverpool (a company spawned by the Automatic Electric Co., USA.) As a bonus he found there a wife who, after they had returned to South Africa, brought four wonderful children into their lives.

A short period with the South African Post Office telephone department convinced Dirk that he did not wish to work for the civil service and he moved on to do development work for the gold mining industry. He produced special two-way underground radio equipment radiating through rock at 350 kHz for use in the mines.

Subsequently he became a partner in a small company manufacturing electronic railway signaling equipment. Dirk retired in 1974, leaving him time to indulge in his special interests such as the history of Electrical Engineering, particularly in South Africa.

In 1986 he visited the USA as a consultant to the South African Broadcasting Corporation Museum and attended the AWA Annual Conference at Canadaigua. While in New York he requested information from the AT & T Archives section relating to the work of the South African, Dr. Hendrik van der Bijl, author of the *Vacuum Tube and its Applications*, published in 1920. In response he was given a pile of photocopies, and included with these was the story of the Western Electric radio developments during 1914/15, which forms the basis of this article.

Apart from historical research Dirk heads a team attempting to start a Science Centre in Johannesburg.