Radio Extension of the Telephone System to Ships at Sea[1]

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SYNOPSIS: The paper describes the development of a two-way radio-telephone system and its use in extending the Bell Telephone System to connect with ships at sea. The electrical considerations and the experimental work involved in determining the system-design of the radio link are discussed. Two land stations were established, one of them a permanent three-channel station on the New Jersey coast. Two coastal vessels and finally one trans-Atlantic liner were equipped. These installations are briefly described in the paper.

The operation of the combined radio and wire system is explained, particularly in respect to the transmission characteristics of the over-all system and the effect thereupon of the movement of the vessel and of variations in atmospheric conditions. Measurements of the variations in the field strength received from field vessels at sea show why it is possible to receive over very long distances at favorable times at night and not during the day. The method of establishing combined radio-telephone-wire circuits to ships is described and representative results are given of the considerable telephone traffic which was handled over the system experimentally during a period of trial operation. Tests of multi-channel telephone operation to several ships through the Deal Beach shore station, and also tests of simultaneous telegraph and telephone operation from the same vessel are described. Connection of a vessel thru the transcontinental telephone line to the Catalina Island radio-telephone system, whereby the vessel in the Atlantic talked with an island in the Pacific, is briefly described, and finally the outstanding conclusions of the entire development work are given.

IN 1919, the American Telephone and Telegraph Company and the Western Electric Company initiated a development program which had for its object the development of a radio telephone system capable of enabling the service of the Bell Telephone System to be extended to include vessels at sea. The program involved extensive development work in the laboratory and field, the establishment of shore and ship stations, and the putting of the system into practical operation, altho on a limited and experimental scale.

It is the purpose of this paper to describe the results of this development work from the standpoint of the complete system, with emphasis upon the general transmission and operating features rather than upon the details of the apparatus developed to perform the necessary functions. The development divides itself, naturally, into two parts: first, the determination of the system-design and the establishment of the necessary stations, and, second, the study of the transmission and operating characteristics of the system.

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Part I

RADIO SYSTEM-DESIGN AND ESTABLISHMENT OF STATIONS

General Plans

The fundamental condition laid down at the beginning of this work was the very general one that there should be developed a system by which any telephone subscriber of the Bell System could carry on a conversation with a telephone station located on a ship, and that, from the point of view of the speakers, the operation should be similar to the carrying on of an ordinary toll call between land wire subscribers. This, of course, involves the development of a satisfactory two-way radio telephone system for ship use. Furthermore, it was desired to be able to carry on three simultaneous and independent conversations between three ships and one land station, since a final commercial system will involve the establishment of several circuits simultaneously. These 2-way transmissions were to be obtained without employing an excessively large frequency band.

A rough study of the problem resulted in a decision to locate the experimental land stations about 200 or 250 miles (320 or 400 km.) apart and to try for reliable commercial transmission to ships at a distance of approximately 200 miles (320 km.).

The transmission problems involved in this work, which were different from those in wire telephone engineering, were:

(a) A much greater variability in the transmission equivalent to be expected in the radio link;
(b) A much greater and more variable interference, both natural and artificial;
(c) A lack of secrecy in the sense of a wire system;
(d) Greater possibilities of cross-talk between channels because of the use of a single medium;
(e) More complication in the matter of signaling and in the setting up of the telephone circuit.

The apparatus problems were, of course, entirely different from those of wire transmission and will not be considered in detail in this paper.

An engineering project of this kind divides itself naturally into two phases; that of the development in the laboratory of systems and apparatus which are technically suitable for the work and, second, the providing in the field of a model system, incorporating the knowledge obtained in the laboratory as a means for enabling the system to be tried out. A preliminary survey of the purely technical problems convinced us that the more important ones were the development of two-way radio telephone apparatus and of multi-channel systems which would operate from a single transmitting station without interference between channels; the design of transmitting apparatus which would satisfy the requirements and which could be built with the vacuum tubes available and the development of a type of receiving system which would provide sufficient selectivity to allow an economical use of the frequency range and at the same time fit in with the two-way system most likely to be adopted. It was decided that during the laboratory development work preparations should be made in the field for providing the necessary experimental stations. This field work as it developed included the location of station sites, the actual construction of the station buildings and the antennas, the equipping of the stations with the apparatus as developed in the laboratory and as further developed in the station, the equipment of the ships, and, finally, the operation and tests of the overall system.

System Design Considerations

In the beginning it was thought that to cover the required 200 miles (320 km.) range about one or one and one-half kilowatts in the antenna would be necessary. It was not known that wave lengths would be made available for this work by the Department of Commerce. To produce this amount of power in the antenna there were available Western Electric 250 watt tubes which it was decided to employ. The question then arose as to the particular type of transmission systems most suitable for the work. The points of importance in solving this problem are as follows:

The greatest economy both in power and in wave length range may be secured by transmitting only one side band of the modulated wave. Moreover, this method has the great advantage that variations in the transmission characteristics of the medium do not cause as great fluctuations in the received signal. This is because the received signal is proportional to the product of the carrier and side bands and if the carrier is supplied locally instead of being transmitted, it is not affected by transmission factors. The use of such a system, however, or of one in which only the carrier is suppressed, throw upon the receiving set the burden of maintaining a constant oscillator frequency not only complicating it but also making reception impossible for the great majority of ships which are equipped with only straight detectors. This would defeat general inter-communication in emergency. Further, it practically restricts the transmitting set to one in which the power tubes are used as amplifiers, and it was known that some difficulty might be experienced in operating a number of 250 watt tubes in parallel if it should be necessary to transmit at wave lengths as low as 300 meters. For these reasons and after some development work it was decided that the proper system to use in the first experiment was one in which modulation is carried on by the constant current method which requires about an equal number of modulator tubes and power tubes and sends out all components of the modulated wave.

The simultaneous transmission of three channels from the land station may be accomplished in several ways. It is possible, for example, to carry on such multi-channel operation from one antenna, which is multi-tuned, or from three separate antennas. The antenna power may be supplied by one system of tubes carrying all three conversations or the power tube system may be split into three parts. Also, using a single antenna simply tuned it would be possible to transmit the three channels from one system of tubes by a system of double modulation which had been installed by the Western Electric Company on United States battleships two or three years earlier. The difficulties which are likely to arise in these various schemes are as follows: The use of multi-tuned antennas involves loss of power in the circuits used to give the antenna three degress of freedom. The use of a single system of power tunes for three channels requires that the tube system be capable of handling a large overload at times without impairment of quality, since it is possible that the peaks of three channels may occur simultaneously. It was expected that under conditions of this kind there would be inter-modulation of the channels due to the modulating action in the plate circuits of the power tubes. The use of three separate antennas located very close to one another and tuned to frequencies differing by three or four per cent. might lead to such close coupling of the three channels that cross-talk and modulation of one channel by another would result, the latter by plate modulation of one set of tubes by the currents induced in its antenna. The use of the double modulation system—altho requiring but one radiated carrier—is open to the objection of overloading and cross modulating of channels and also to the objection that the receiving apparatus aboard ship must be more complicated. An analysis of these and other proposed methods of operation resulted in the decision to employ at that time three separate but closely adjacent antennas and three separate transmitting sets using the constant current modulation system. This choice was made because of conditions peculiar to this particular problem and to the vacuum tubes then available. Of course, improvements can be made in the system at the present time as a result of the information obtained in the development using the very much larger vacuum tubes now available.

These decisions, therefore, determined the general type of system to be used, namely, one in which many of the known advantages of single side band transmission were sacrificed in order to secure simple apparatus, to make use of then existing power tubes and to enable the transmission to be received generally.

The problem of securing the two-way operation necessary aboard ship and for combined radio and wire operation may be attacked in several ways. In general, there are three methods available:

(1) In which the east and west channels are established alternately and not simultaneously, by switching. The push-button scheme is a familiar example, although unsuitable for tying in with the wire telephone system. Another arrangement is the use of voice-operated relays to throw the terminal apparatus into the sending or reciving condition, depending upon the direction of transmission.

(2) The use of the principle of balance to separate the outgoing from the received transmission. The radio receiving antenna circuit is balanced with respect to the transmitting antenna circuit.

(3) Employment of different frequencies for the two directions of the two-way transmission, relying upon frequency-selecting circuits for affecting separation. The first two methods allow of operation on the same or on different carrier frequencies.

All of these fundamental methods were considered in their several possible embodiments, and compared from the standpoint of the conditions to be met in the radio system itself and in linking it with a public service telephone system. The system finally adopted employed different frequencies for sending and receiving and secured discrimination by frequency selection supplemented at the land station by a moderate degree of special separation and balance. By using sharply selective receiving circuits, a moderate frequency difference between east and west channels sufficed to give the necessary degree of separation.

Preliminary Tests

By the time these decisions had been made there was available for experimental purposes a plot of land near Cliffwood, New Jersey. It was decided to construct a model of the proposed antenna system on this plot and to operate small transmitting sets to determine the cross-talk and other important conditions. The antenna system decided upon consisted of three poles arranged in the form of an equilateral triangle supporting three antennas—one from the middle of each span to the transmitting shack at the center of the triangle. The dimensions of this model system were 50 meters (164 ft.) by 10 meters (33 ft.) high. Three experimental transmitting sets of small power were set up under the antenna system and studies were made of the interference produced between channels when all three channels were in use. Three receiving sets of the general form proposed were built and taken to a location near Elberon, New Jersey, about 16 miles (26 km.) from Cliffwood, at which place it was decided to locate the three-channel receiving station to co-operate with the New Jersey transmitting station a mile (1.6 km.) away.

In November, 1919, the first test of a three-channel system was held between Cliffwood and Elberon with the result that the receiving sets resolved conversations on carriers of frequencies of 725, 750, and 775 kilocycles without any cross-talk altho the received volume was so large as to be audible all over the room. This is a frequency difference between channels of approximately three per cent. A change in frequency to 747, 759, and 777 kilocycles resulted in a barely perceptible cross-talk on the middle channel, with no cross-talk on the others. These results indicated that the loop receivers which had been developed were sufficiently sensitive and selective to carry out the proposed three-channel work; and, altho a great deal of development work was done later on the receiving sets, the general principles were retained. It was found that some reliance must be placed upon the directional properties of the loop antennas, and considerable care was used to secure very sharp directional selectivity. This was done by compensating for the vertical antenna effect of the loop by a balanced connection to ground.

During the whole course of this ship-to-shore work very little trouble was experienced thru interference by continuous wave stations, even when their frequencies came within two or three per cent. of those to be received. We did, however, have much difficulty due to interference from spark stations, since they inherently occupy a wide frequency range.

Provision of Stations and Development of Apparatus

During the time the model system was being constructed at Cliffwood, land had been purchased at West Deal, Monmouth County, New Jersey, for the permanent transmitting station. This station as it now appears is shown in Fig. 1. The permanent building was preceded by a temporary structure to house an experimental transmitting station which could be used as a model for the design of the four final sets to be located in the permanent building.

Preliminary studies were also made to determine the proper form to give to antennas suitable for three channel operation without excessive cross-talk, and this study indicated that by the use of series inductance and capacity the antennas could be stiffened enough to prevent excessive coupling effects and still pass the required frequency band.

While this work was going on, a two-way telephone set for use aboard ships was developed, and in the spring of 1920 one of these

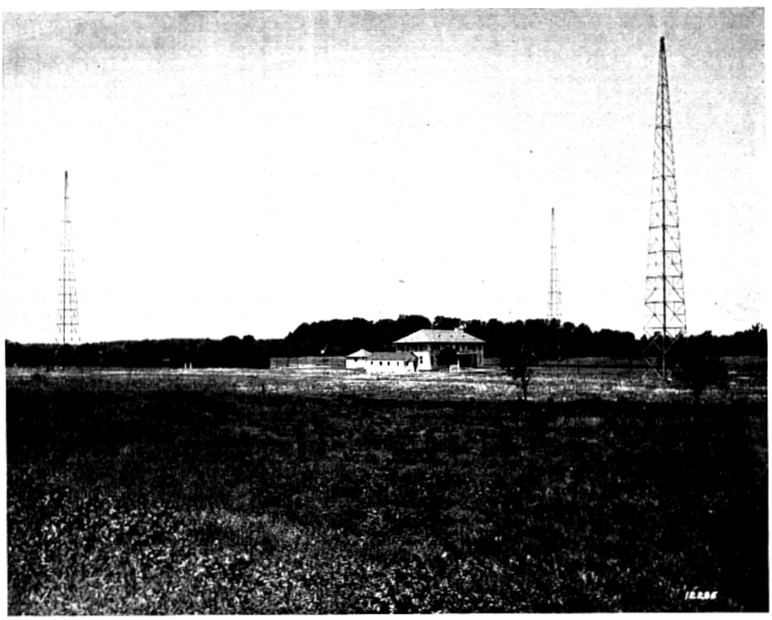


Fig. 1

sets was installed aboard the steamship *Ontario* of the Merchants and Miners Transportation Company. Experimental communication with this ship, by means of the model transmitters at both Deal Beach and Green Harbor stations, showed that commercial operation, at least for one channel, could be maintained.

By the fall of 1920, the construction work on the four transmitting and receiving channels was completed and early in December a demonstration of simultaneous three-channel operation from this station to ships was carried out with satisfactory results.

Fig. 1 shows a general view of the outside of the transmitting station at Deal Beach. The three steel towers form an equilateral triangle of sides five hundred feet (150 m.) and each is one hundred and sixty-five feet (50 m.) high. Steel cables to support the antennas are strung between these towers and also three cables extending inward support a fourth antenna which rises directly from the building in the middle of the triangle. One antenna goes to the middle of each of the first mentioned steel cables, so that there are a total of four transmitting antennas. One of these is intended for use at six hundred meters. The building is thirty by ninety feet (9.1 by 27.3 m.) and two stories high. The southern half comprises the operating room which rises two full stories. The other part of the building is taken up by an office, shop, power room, living and dining room and kitchen, and by six bedrooms.

Description of the Experimental Radio Stations

The system as developed at Deal Beach consists of four transmitting sets, operating into four separate, altho naturally coupled, antennas, one set and antenna being intended primarily for 600 meter calling and for emergency. The receiving station co-operating with Deal Beach is located about a mile (1.6 km.) north of that station and contains four receiving sets receiving energy from four loop antennas. The transmitting sets are capable of putting about one kilowatt of modulated radio frequency power into each antenna and are controlled from a telephone switchboard into which run trunk lines from New York City. A ten-pair telephone cable connects Deal Beach and Elberon and another telephone switchboard at Elberon permits the transfer of received signals back to the wire line. The radio station operates, therefore, generally as a telephone repeater arranged for two-way operation with two repeaters. At the ship stations, because of the small amount of space involved, transmitting and receiving was accomplished on the same antenna at different frequencies in the two directions. Because of the better receiving conditions on the shore the proper transmission balance was obtained by making the output of the ship transmitting set about one-quarter that of the land station.

The general principle of operation of one channel of the wire-to-radio repeater will be described from the schematic circuit diagram of Fig. 2, which shows, in the dotted blocks, one channel of the transmitting station, a ship station, and one receiving set. At the transmitter station the master oscillator, very carefully shielded to maintain constant frequency, operates into a two-stage amplifier, the last stage being fifty watt tubes, and from there into a bank of six radio frequency power tubes, each with a rating of 250 watts plate dissipation. Speech to modulate this radio frequency output enters from a telephone line and is applied to a speech amplifier the output of which operates into a bank of 250 watt modulator tubes in parallel. Thus both the radio frequency and the speech frequency currents are brought up to the high power level before modulation takes place. The six radio frequency and six speech frequency tubes have their

TWO-WAY RADIO-WIRE SYSTEM

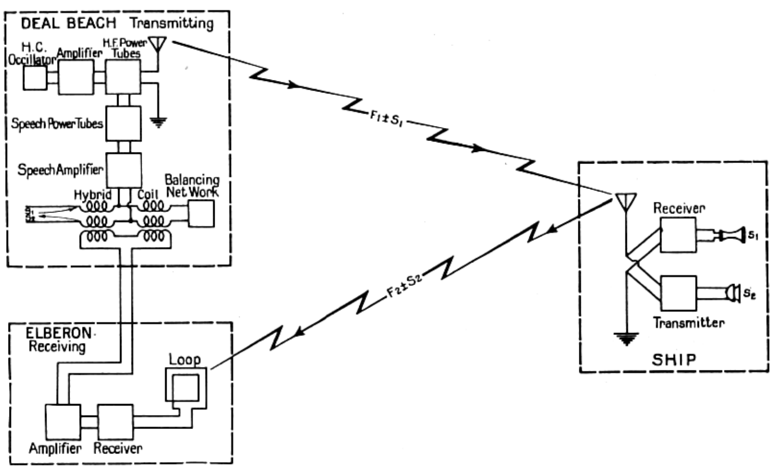


Fig. 2

plate circuits connected together and operate as a constant current modulation system. Thus current of the frequency F_1, generated by the master oscillator and amplified and modulated, is radiated from the antenna. The notation $F_1 \pm S_1$ indicates the radiation of the carrier and two side bands from this antenna. The incoming speech S_1, as it comes from the telephone line, passes through the hybrid coil and to the balancing network shown. This balancing network has an impedance characteristic similar to that of the incoming line, and the combination of hybrid coil and network is similar to that used in telephone repeater practice to secure two-way operation. The object of this arrangement is, of course, to prevent signals, coming in from the receiving station, operating upon the transmitter of the outgoing channel. If the balancing network is an exact picture of the incoming line and if the hybrid coil is properly made, incoming signals for transmission west on the telephone line will produce no voltage at the terminals of the transmitting amplifier.

At the receiving station the incoming wave is impressed upon a loop antenna and the receiving set. The resulting detected output is then amplified as indicated and returns to the hybrid coil, passing out on the telephone line without producing a voltage on the speech amplifier of the transmitting set if the hybrid coil balance is perfect.

On the ship, this physical separation of transmitting and receiving set is, of course, not practical, and, as indicated before, transmission and reception take place upon one antenna so arranged that the receiving circuit offers a high impedance to currents of the outgoing frequency and low impedance to the incoming signal. Actually,

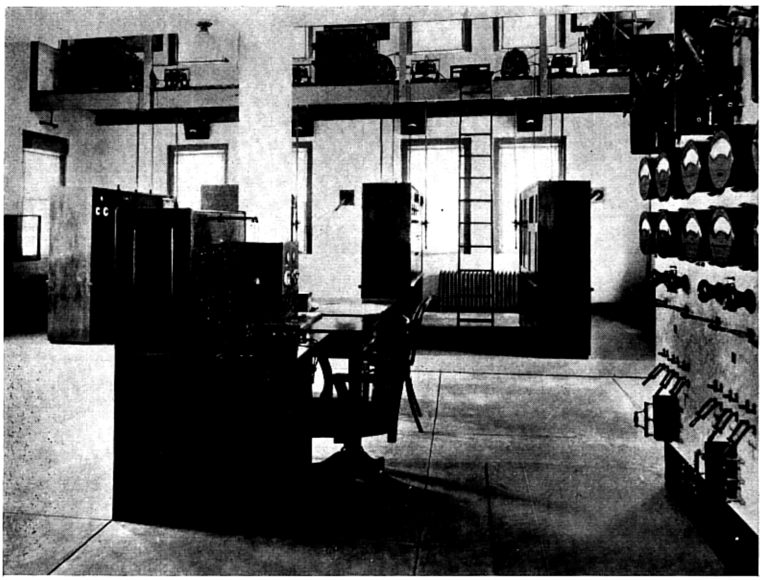


Fig. 3

the outgoing signal is not entirely excluded from the ship's receiver and there is present a side tone of about the magnitude of the incoming signal. This is by no means an undesirable condition and is the one which holds approximately in an ordinary telephone subscriber's instrument. The presence of side tone assures the speaker that his system is functioning properly.

Fig. 3 is a view of the operating room showing the four transmitting units at the back; the power switchboard for supplying the plate circuits of the tube at the right; the telephone switchboard for the four speech or telegraph channels in the center; and on the gallery above the transmitting units, the coupling coils, loading inductances, and so on, between the sets and the antennas. The motor generator sets capable of supplying as much as five kilowatts at eighteen hundred volts to each of the transmitting sets are located in an adjoining room and controlled from the operating room.

Fig. 4 shows the interior of one of the transmitting units. In the shielded box at the upper right hand corner is the master oscillator which sets the frequency to be used for that particular channel.

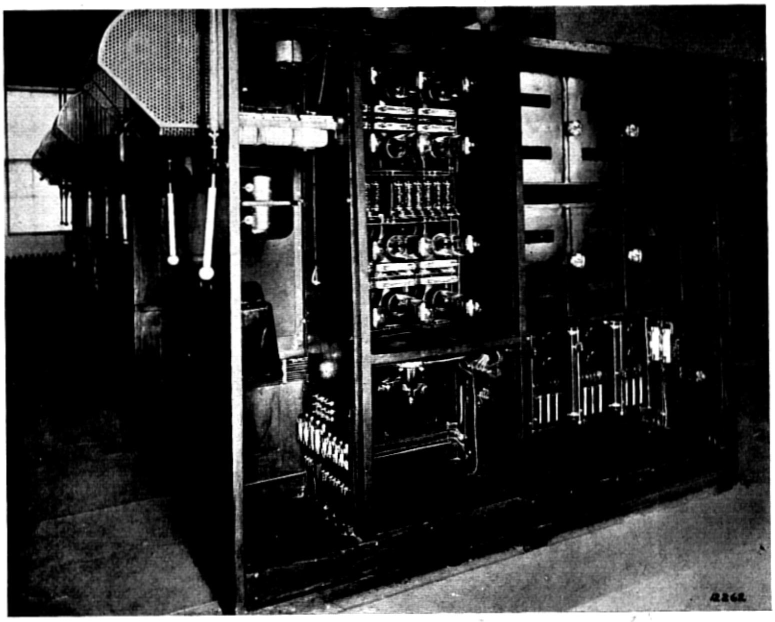


Fig. 4

Next to the left are two more shielded compartments, each of which contains an amplifier. The last stage of this amplifier employs a fifty watt tube. In the larger unshielded compartment are located above, the six radio frequency power amplifier tubes. The reason for introducing two amplifiers between the master oscillator and the power tubes is to prevent any reaction from the attenna circuit back to the master oscillator. By taking this precaution the frequency of the master oscillator never varies more than fifty cycles in eight hundred thousand. The lower set of shielded compartments, at the right, contains the audio frequency telephone amplifiers which supply currents to the six modulator power tubes shown in the lower par of the open compartment. These two sets of six tubes each are connected together to secure constant current modulation. The output of these twelve tubes is led to terminals on the output of the transmitter unit at the left. To secure cooling in hot weather, a fan is installed below the power tube compartment. In the extreme left compartment are shown choke coils in the power circuits, and at the extreme left on the outside are circuit breakers and two handles for operating the tuning and coupling apparatus in the gallery above.

Fig. 5 shows one set of radio frequency apparatus in this gallery. The two inductometers at the left are for coupling and tuning, and

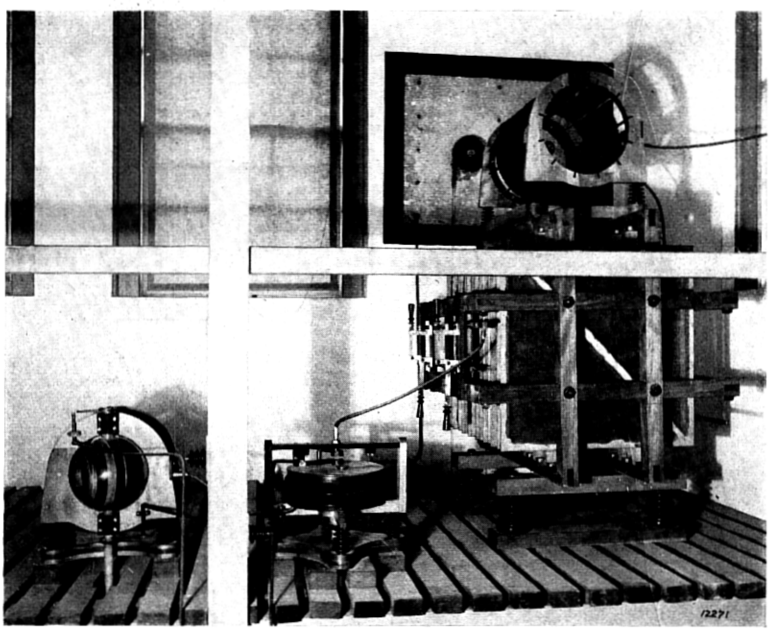


Fig. 5

the large condenser at the right, the plates of which consist of brass frames covered with copper window screen, is inserted in series with the antenna. This capacity together with the inductance immediately above it stiffens the antenna circuit and increases the frequency selectivity to prevent radio frequency interaction between the several antennas.

The telephone switchboard shown in Fig. 6 is a special type of P. B. X. (private branch exchange), constructed to provide the necessary shielding and to include telegraph oscillator, phantom coils, and other special apparatus. This switchboard provides for four channel telephone or telegraph operation and for the control and monitoring of all channels. In the operation of the system one operator, located at this switchboard, has complete control of the entire transmitting plant. The operating board was especially built

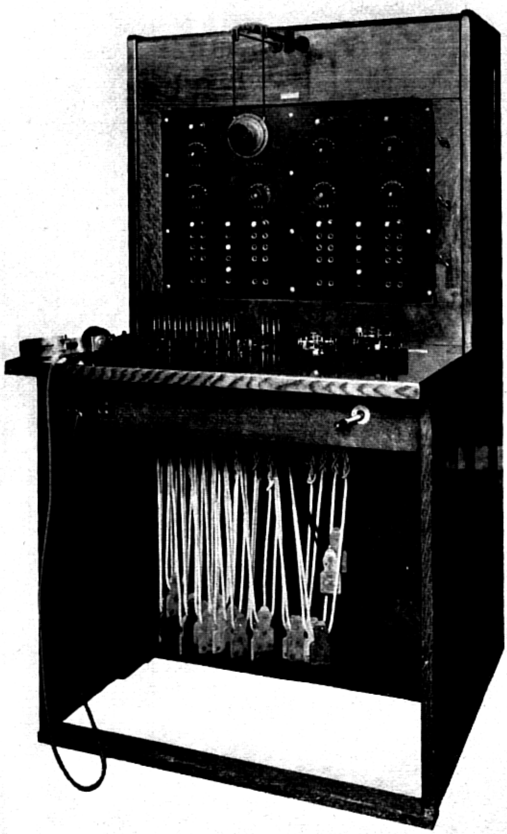


Fig. 6

for the experiments, and altho not the final form contains features which are of interest in that they illustrate well the technique involved in combined wire and radio operation.

The four vertical rows of jacks correspond to the four two-way radio channels. At the top of each row will be seen the dials for controlling amplification. On the apron are telegraph keys, telephone keys, and operating cords. The cord circuits, by being plugged into the jacks, interconnect any one of the New York toll circuits with

LAND RADIO STATION OPERATING CIRCUITS

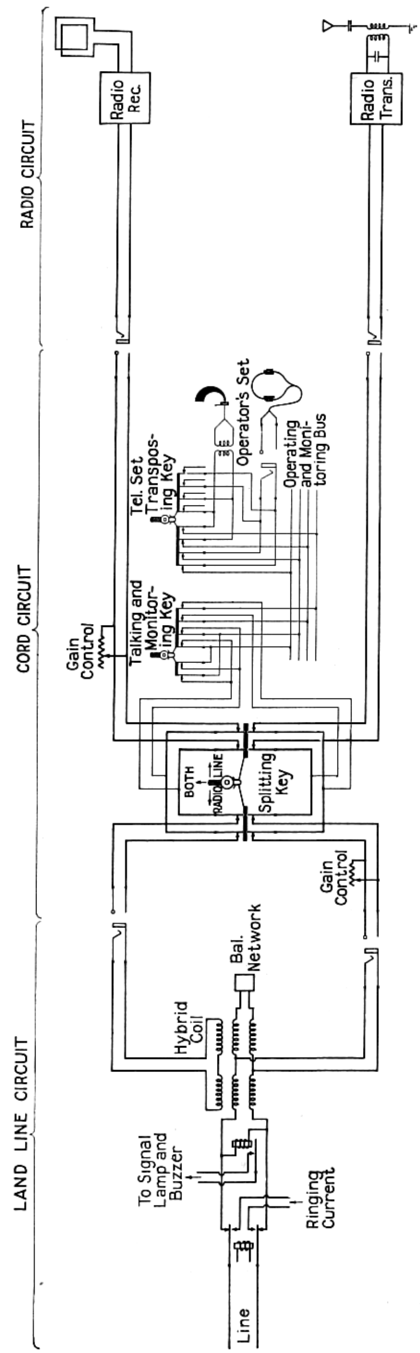


Fig. 7

any one of the four radio circuits. The cord circuits contain the switching keys seen in front, by means of which the radio station operator is enabled to split the circuit and talk either way, connect the circuit thru and bridge on it and talk or monitor. This cord

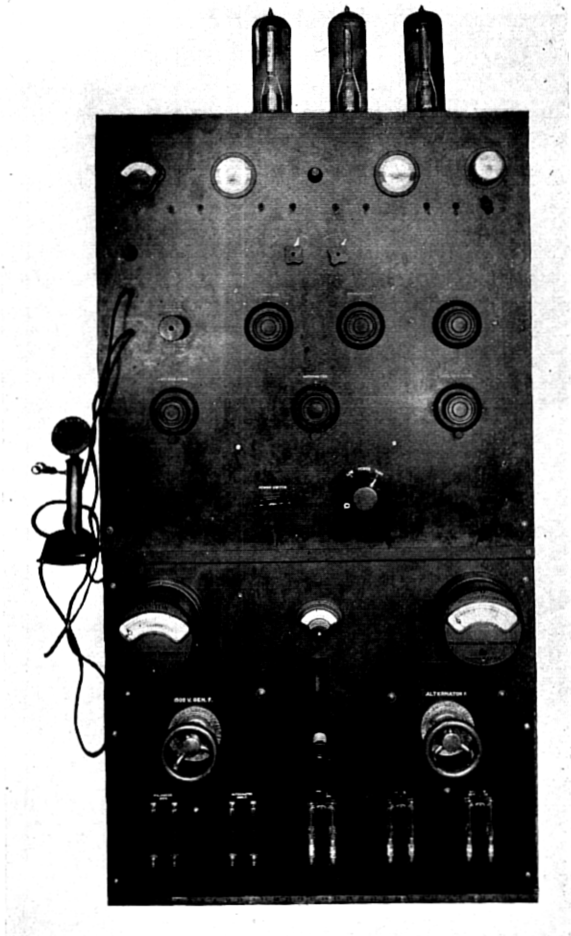


Fig. 8

circuit is shown in Fig. 7 in relation to the rest of the wire-radio junction circuit. It will be seen to be of a four-wire instead of the more usual two-wire type and to comprise in reality two circuits, one for east-bound and the other for west-bound transmission. This arrangement was used in order to obtain flexibility in the experiments. It enables the circuits to be continued inland as four-wire circuits and permits of the switching operations being carried out with a minimum effect upon the 2-way balance of the transmission system.

The receiving station at Elberon is located on a rented plot of ground and was not built in permanent form, since we did not regard this location as entirely suitable for receiving from the Atlantic. Reception is carried on the four channels by means of four loop antennas operating into four receiving sets. A telephone switchboard similar to that at Deal Beach provides for the connection to the wire system. Of course, two telephone switchboards are not necessary but one was installed at each station in order that we might determine by operating tests whether the control of the system should be from the transmitting or the receiving station.

The receiving sets as finally developed were extremely selective and pass only a band of speech width with a large attenuation outside this band. They will be described in another paper.

Fig. 8 shows a front view of one of the experimental transmitters used aboard ship. The lower half consists of power control apparatus. Three 250 watt tubes are used of which one is a master oscillator, one a power amplifier and one a modulator. The large capacity tube was used as a master oscillator and only a very small part of its output applied to the second power tube. This was done in order to prevent reaction of the antenna system upon the oscillator.

Apparatus of this type was installed on the *Ontario* and *Gloucester* of the Merchants and Miners Line, and operated in conjunction with Deal Beach and Green Harbor. Later another electrically similar set was built by the General Electric Company and was installed and operated by the Radio Corporation on the steamship *America*. This installation is illustrated in Fig. 9.

PART II

OPERATION OF THE COMBINED RADIO AND WIRE SYSTEM

The development work as described in Part I had resulted in establishing an experimental ship-to-shore radio telephone plant of some proportions. This will be seen by reference to the accompanying map of Fig. 10 which gives a picture of the field setting, as it were, of the experimental operations. The experimental plant included:

Two operating shore stations—Deal Beach, New Jersey, and Green Harbor, Massachusetts.

A field experimental station at Cliffwood, New Jersey.
Two ship installations, on the S. S. *Gloucester* and the S. S. *Ontario.* The vessels operated between Boston and Philadelphia or Baltimore

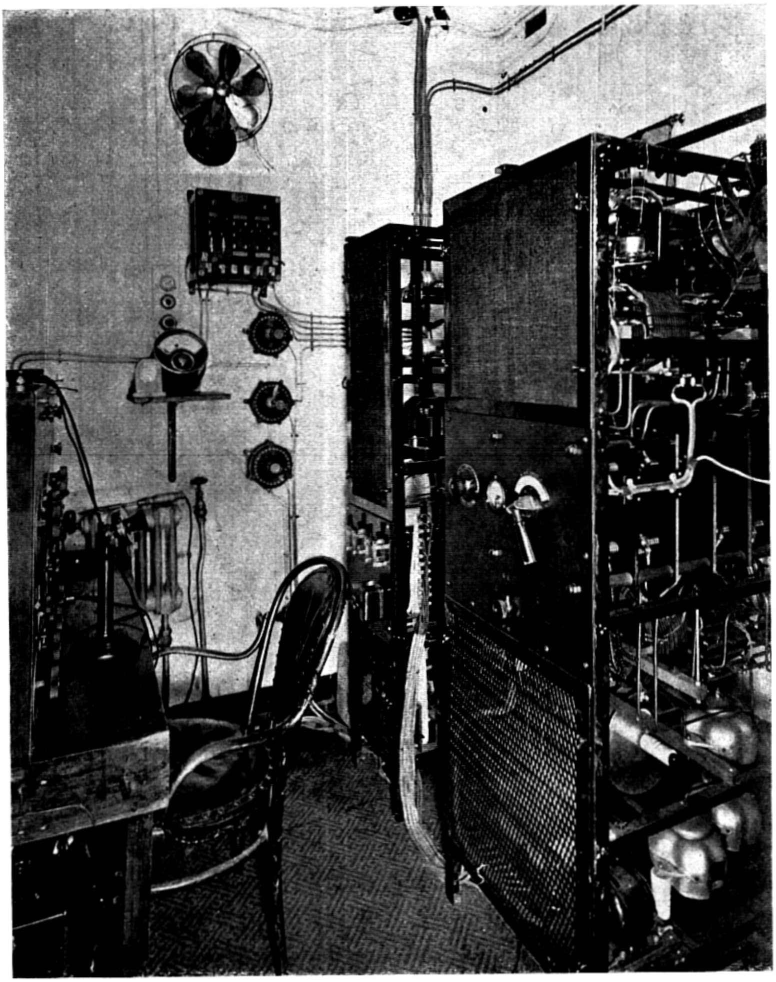


Fig. 9

and took any of several courses, two representative ones of which are as plotted in the figure.

Let us now consider this plant from the communication standpoint and look into its characteristics, first as an electric transmission system, and then as a message handling facility.

Each of the two land stations was tied into its nearest center by wire circuits, Deal Beach to New York and Green Harbor to Boston. We will take for our example the New York-Deal Beach-Ship circuit pictured in Fig. 11 and shown diagrammatically in Fig. 12. This is

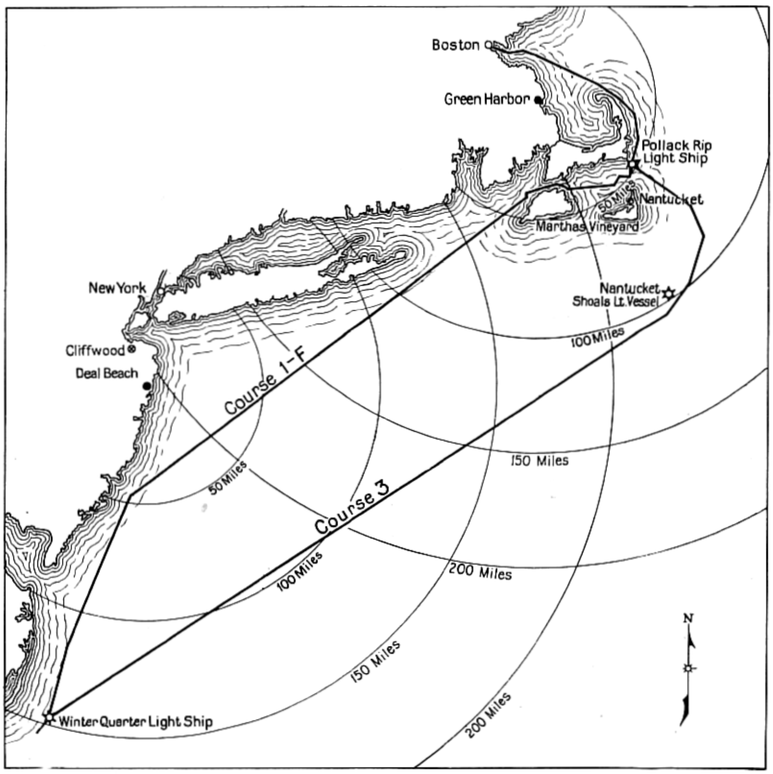


Fig. 10

a combination of wire-radio toll circuit, one end of which terminates on a vessel of variable position and the other end of which is capable of being extended either over a local circuit to a New York subscriber or over a long distance circuit to reach subscribers at more distant inland points.

This communication circuit must fulfil two general requirements. In the first place it must be so constituted electrically as to preserve the feeble voice currents launched upon it by one subscriber so that they be rendered to another person with sufficient volume and fidelity of wave shape as to be readily intelligible. This requires that the circuit be properly engineered as an electrical transmission network.

Secondly, given a circuit capable of talking, it is necessary that this circuit be flexible in use so that it can be put at the disposal of any land line subscriber for connection to a ship at sea, at any time the ship is within range. This requires that the proper switching facilities be provided and brings in operating and traffic problems.

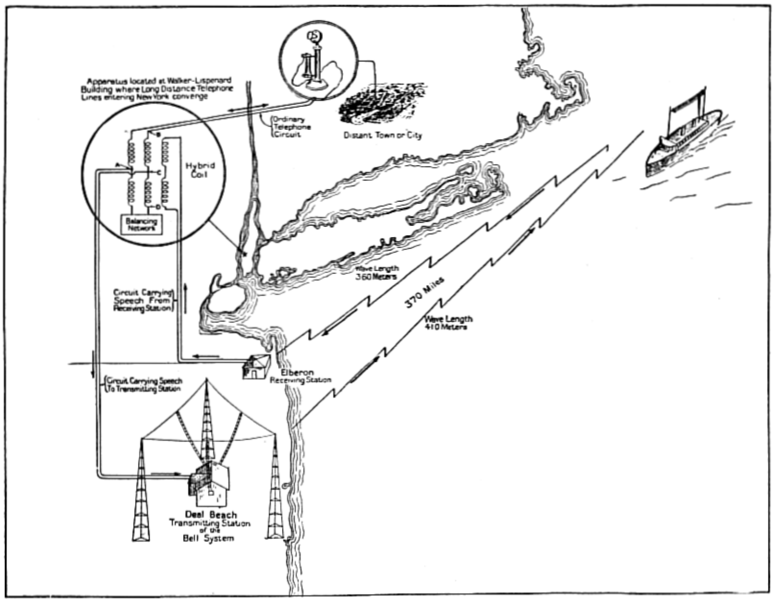


Fig. 11

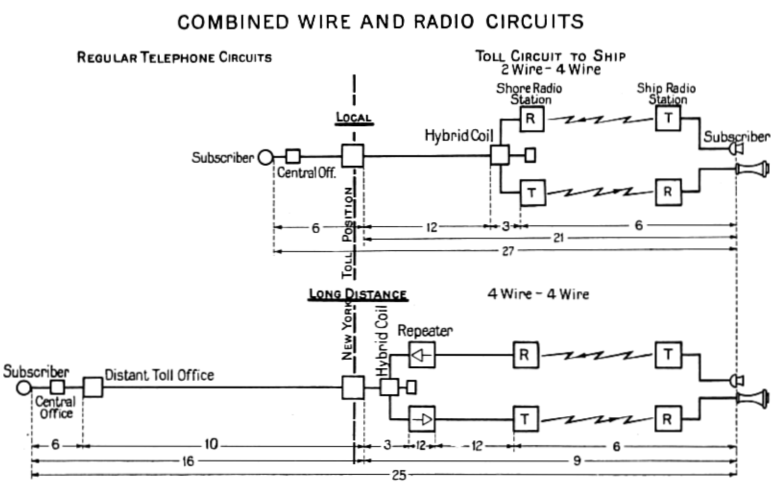


Fig. 12

The Radio-Wire Transmission Circuit

Two types of circuits were used in the experiments in operating between New York and the vessel, as shown schematically in Fig. 12. The radio link is the same for both. Different frequencies are used for transmitting in the two directions so that in the radio link we have the equivalent of two circuits, one for transmitting east and the other for transmitting west. This is the same as the four-wire telephone circuit. In the thru circuit first shown the radio four-wire circuit is brought into a two-wire circuit at the land radio station, making a regular two-wire telephone circuit from the radio station to the New York toll terminal. This circuit was used in the tests for calls local in New York. In the arrangement of the second circuit of Fig. 12, each of the one-way radio channels is extended back to the New York toll office by its own wire line and there joined into a two-wire circuit, making the wire-radio toll line from New York to the ship a four-wire system. This arrangement forms a high grade circuit and is the one used in the experiments for connecting with long distance lines.

Taking the four-wire circuit, the path of the voice currents may be traced thru from one end to the other as follows: The currents which are initiated by the land subscriber, for example, upon arrival at the New York toll office divide in the hybrid coil between the east-bound and the west-bound circuits. The currents are prevented from being propagated over the west-bound branch because of the unilateral nature of the repeater. The currents of the east branch are amplified in the repeater of this circuit in order to make up for the attenuation suffered in the cable circuit, and upon arrival at Deal Beach are amplified to power proportions, modulated upon the radio carrier and radiated into space. Upon being received at the ship end of the radio circuit they are sharply selected in respect to frequency, are again amplified, and delivered to the listener. When the ship subscriber talks, the voice currents are amplified, pass directly into the radio transmitter, are transmitted over the radio link in the usual way, received at the shore station, amplified and sent out over the wire circuit to New York. Here they pass in the reverse direction thru the hybrid coil and divided between the two-wire circuit on the one hand and the balancing network on the other, thus getting back into a regular two-wire telephone circuit.

Interconnection Between Radio and Wire Circuits

It will be well to recall at this point just what it is that makes possible automatic repetition or thru transmission between the wire and radio circuits.

There is both an outgoing and an incoming radio channel. The automatic repetition from the wire to the outgoing radio channel is made possible thru ability to control the transmitter wave power by the voice currents set up at the distant end of the telephone line. It will be recalled that in the early radio telephone art, before the vacuum tube, modulation was effected by the microphone transmitter which required that the talker be present at the radio station. It is, therefore, the electric-control type of modulator such as the vacuum tube, as distinguished from the air-wave control modulator, which permits of the talker being at the far end of a wire circuit. Conversely in the receiving channel, it is the fact that the detecting action yields telephone currents directly, ready for propagation over a wire circuit, that enables the radio channel to be extended to a distant listener.

Thus it is the thermionic tube modulator and detector which have made possible the radio-wire transfer. It is the thermionic tube as a reliable high-quality amplifier, however, that makes the transfer practical; for it is the amplifier which enables the weak voice currents received at the radio station from a land line subscriber to be boosted to power proportions and thus control the considerable radio frequency power required for transmission; and, again, it is the amplifier which enables the extremely weak currents received from the radio link to be so augmented that upon being placed upon a wire circuit, and perhaps being further amplified en route, they may be heard in the regular telephone at the other end.

The other important feature of the radio-wire inter-connection is the junction of the four-wire and the two-wire circuits by means of the hybrid coil and balancing network as shown in Fig. 11. The windings of such a coil are so designed as to establish a sort of Wheatstone bridge circuit. This bridge circuit accomplishes the joining of the regular two-wire telephone circuit with the sending radio channel on the one hand and the receiving radio channel on the other, while still maintaining an electrical separation between the two radio channels. It is really, therefore, the connecting link between the two-wire type of circuit of the telephone plant and the four-wire circuit of the radio link. The hybrid coil type of circuit is taken from the telephone repeater and carrier current art.[2] The radio receiving circuit corresponds to the generator branch of the Wheatstone bridge, and radio transmitting circuit to the detector branch. The

[2] "Telephonic Repeaters," B. Gherardi and F. B. Jewett, *Journal of American Institute of Electrical Engineers*, pages 1255–1395, November, 1919.

"Carrier Current Telephony and Telegraphy," E. H. Colpitts and O. B. Blackwell, *Journal of American Institute of Electrical Engineers*, pages 205–300, February, 1921.

two-wire telephone line corresponds to the "X" arm of the bridge and the balancing artificial line to the "Y" arm. The ratio arms are in effect formed by the windings of the hybrid coil.

Speech Received from Ship Re-Transmitted from Shore Station

Now this junction circuit always has some unbalance because it is obviously impossible to maintain a perfect symmetry between the telephone line and the balancing network. Especially is this true where the telephone line is a type not designed for repeater operation and is switched at its terminal to any of a number of lines of different impedances, as was the case with the circuit used in the tests.

This unbalance between the line and its balancing network will be seen to permit some of the speech-current received over the radio link to get across into the transmitting circuit, to modulate the shore station carrier and to get out into the ether again on the transmitting wave length. As a matter of fact during the experiments the unbalance was sometimes such as to permit of fairly strong transmission around back thru the shore transmitter, so that incoming speech was repeated out thru the shore station transmitter in amplified form. This enabled listeners in the vicinity of New York to hear the conversation originating on the ship almost as well as that originating on land, and they naturally thought that they were picking up the ship's radio transmission directly, whereas they were actually overhearing the re-transmission of the shore-station's reception.

The Thru Circuit as a Repeated Telephone Circuit

This re-transmission makes all the more evident the true role of the shore station, namely, that of a large telephone repeater between two sections of line, the one a land line and the other a "space" line, and functioning also to convert between the voice frequencies of one section and the radio frequencies of the other. As such, we can consider the over-all circuit from a transmission standpoint much as we do long distance repeated telephone circuits.

Now one of the most important transmission considerations in such a long distance circuit is that of how the amplification is applied in relation to the losses in the circuit. This question of amplification is particularly important in the case of combination radio-wire systems, because the radio circuit possesses inherently large transmission losses and requires correspondingly large amplification. The necessary large amplification is supplied at both ends of the radio link, partly in the transmitting station where the voice currents are amplified up to power proportions and partly at the receiving end where the amplification is likewise large altho at small power. In the radio telephone circuits which were operated in the experimental work the power in the sending antenna to that in the receiving antenna is in the ratio of roughly 10^{10}. This requires amplification which was distributed somewhere near equally between the sending and the receiving ends. It has been found convenient to express such transmission losses in terms of a power ratio using $10^{0.1}$ as a unit.[3] Thus the above antenna to antenna power ratio would correspond to 100 of such units.

Circuit Transmission Equivalents

It is necessary that the amplification of such a circuit be sufficient to offset very closely the loss, in order that the net loss be small. Actually, in the tests, the radio portion of the circuit was worked with a net transmission loss of about six units, meaning that at least 95 per cent. of the radio over-all circuit losses were wiped out. This means that if a change of say 10 per cent. occurs in the amplification, or in the ether loss as by fading or movement of the vessel, the circuit equivalent will be greatly affected—changed by about 200 per cent. The difficulty of maintaining the ship circuit stable will therefore be appreciated.

Fig. 12 shows the transmission loss (of six units) obtained for the radio link during the tests and also the other losses which are in the wire portion of the combination system. The distribution of losses in the first circuit will be noted to be approximately as follows:

6 units in the radio link.
3 units in the hybrid coil—balancing network.
12 units in the wire circuit to New York.
6 units from the New York central office to the subscriber.

[3] The unit used in this paper is one which has been found convenient in which expressing the transmission loss or gain of a circuit. One unit is taken as that power ratio which is equal to $10^{0.1}$. Thus, if the attenuation or amplification of a circuit is one unit the power at the two ends are in ratio of $10^{0.1}$; if ten units, in the ratio of $10^{10 \times 0.1}$ or 10; twenty units would therefore have a power ratio of 100, and so on. The advantage of using a power ratio instead of a current ratio is that it is undependent of the impedances of the two portions of the circuit considered. The advantage of expressing the power ratio as an exponent is that on account of the exponential nature of attenuation it enables the net transmission efficiency of a system to be readily derived by algebraically summing up the individual losses and gains. This unit has been selected as more suitable for general use in expressing transmission efficiencies than the 800 cycle "mile of standard cable" which has sometimes been made. The ratio between these two units is as follows: 1 mile of standard cable equals 0.95 units as used in this paper. $\frac{P_1}{P_2} = 10^{0.1} = \frac{1}{0.95} \epsilon^{(0.109)}$ units.

This makes a total loss between subscribers of 27 units which is satisfactory for a good talk under fairly quiet conditions. This equivalent was usually realizable under the conditions of the test and the majority of the calls put thru from local stations in New York with the ship 100–200 miles (160–320 km.) out were successful despite occasional spark interference in the radio circuit.

The transmission loss is, however, too high in such a circuit to enable it to be extended inland over long distance wire circuits. If this is attempted, two limitations come into play. In the first place, the volume of the talk becomes too weak. If the call were extended over a toll circuit having a 10-unit equivalent, for example, the overall equivalent would become something like 37 units, which is excessive. This could be overcome to some extent by a cord circuit repeater at New York. A second limitation which existed in the experimental set-up resided in the unbalance between the line and the balancing network at the radio station. This unbalance permitted currents received over the radio link to be fed back thru the radio transmitter of the land station, as described above. These fed-back currents overload the radio transmitter if they are large compared with the currents being supplied to the radio transmitter from the shore subscriber. In other words, if there is sufficient amplification in the shore transmitter to enable very weak voice currents arriving over a line of high equivalent to load the transmitter fully, then the transmitter is likely to be overloaded by currents which get through the hybrid coil from the associated radio receiver. For these reasons, the two-wire-four-wire circuit of Fig. 12 is not good enough for extension over long distance circuits.

The four-wire type of circuit which is suitable for long distance land line connections is shown in the second diagram with representative transmission equivalents. A brief comparison of the two-wire and the four-wire circuits will make it evident why the four-wire circuit gives the better equivalent. It enables the land line loss between the radio station and the toll center to be more or less wiped out, thus in effect placing the radio station electrically at the toll center. Another way to express the situation is this: regard the hybrid coil unbalance as the limiting factor, then assume that, while holding to a given unbalance, the four-wire circuit (the loss in which can be largely wiped out by one-way amplifiers) is extended inland. The length of the remaining two-wire line back to the land subscriber is thereby decreased and the ratio of the current received at the radio station over the line as compared with that transmitted across the hybrid coil thru unbalance is increased. It will be observed that with the circuit conditions as illustrated, the over-all equivalent between, say, a Chicago subscriber and a ship, including a 10-unit toll circuit loss, is approximately 25 units, which should give a good talk.

Power Levels and Interference

It is necessary that the magnitude of stray currents be so kept down in comparison to the transmission currents thruout the system as to obviate noise interference with telephone conversation. This requirement is particularly difficult of realization in the radio link because of static and, especially in the vicinity of New York, interference from spark telegraph stations. It is, of course, this interference, caused by the presence in the ether, on the wave length band being used, of extraneous wave components, which sets the actual range limit of the radio link. Actually it was found that in transmitting on about 400 meters in the vicinity of New York the receiving field strength could not be permitted to go on the average below about 200 micro-volts per meter, and even then the spark situation is so bad in the present art as to give periods of prohibitive interference. In less congested zones along the coast to the north, probably lower field strengths could be permitted.

Transmission Variations in Radio Circuit

One of the outstanding transmission characteristics of a ship-to-shore radio telephone system is the variation which the attenuation of the radio link undergoes as a result of the movement of the vessel. In order to determine the magnitude of these variations, a series of measurements were made of the telephone transmission over the radio circuit as the vessel proceeded on her course.

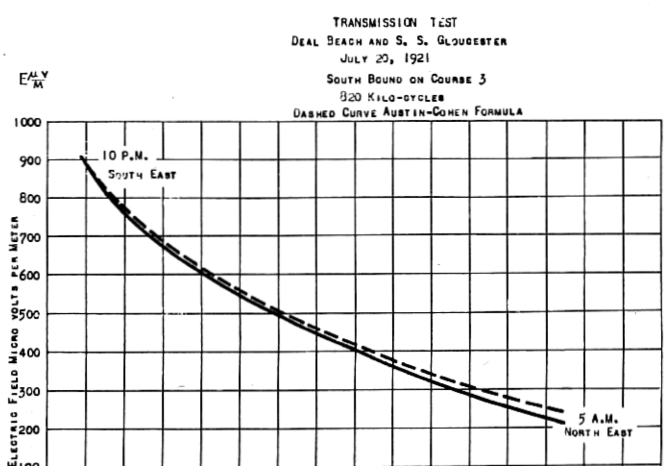
The method of making these measurements is shown schematically in Fig. 13. Take for example the case of measuring a one-way circuit as distinguished from a circuit looped back. A 1,000-cycle current of predetermined power of the order of one miliwatt is impressed upon the input circuit of the radio transmitter. This tone is received in the output of the distant radio receiver. There it is passed to the measuring apparatus where it is amplified, rectified, and made to operate an indicating instrument. The receiving end measuring apparatus is then switched to a local source of 1,000-cycle current giving the same power as was applied to the transmitter at the sending end. The proportion of this power which enters the measuring apparatus is then varied by a variable network calibrated in power ratio loss (it was actually in miles of standard cable) until the indicator reading is the same as that obtained from the radio receiver. The setting of the variable network then indicates the transmission loss of the circuit. The method is similar to that developed for measuring

mile. This was one of the cases where the vessel was well south and close in shore and, of course, represents very poor transmission. It means that with the vessel traveling as slowly as ten miles (16 km.) per hour, a transmission change of about five units per hour will occur. In telephone practice it is desirable to keep the transmission equivalent constant to within two or three units, so that this condition would require re-adjusting the amplification as often as every half hour.

These curves show the necessity for so designing th

portion of this curve is for straight-out-to-sea transmission where the attenuation law is seen to be normal.

In the field strength measurements made during the ship-to-shore development, those of the S. S. *America* en route across the Atlantic are especially illuminating. The results are given in Fig. 20. The vessel was in-bound so that the curve develops from the right to the left, altho the effect is just the same as if it developed in the reverse direction with the vessel out-bound as was shown by another set of measurements which gave generally similar results. The actual measurement results are indicated by the points and by the con-



as during the best times at night. These enormous day to night fluctuations are now familiar to broadcast listeners. This curve shows the impossibility of giving continuous ship-to-shore telephone service at these relatively short wave lengths for distances as great as 1,000 miles (1,600 km.). For such distances much longer wave lengths will be required, as well as more sending power.

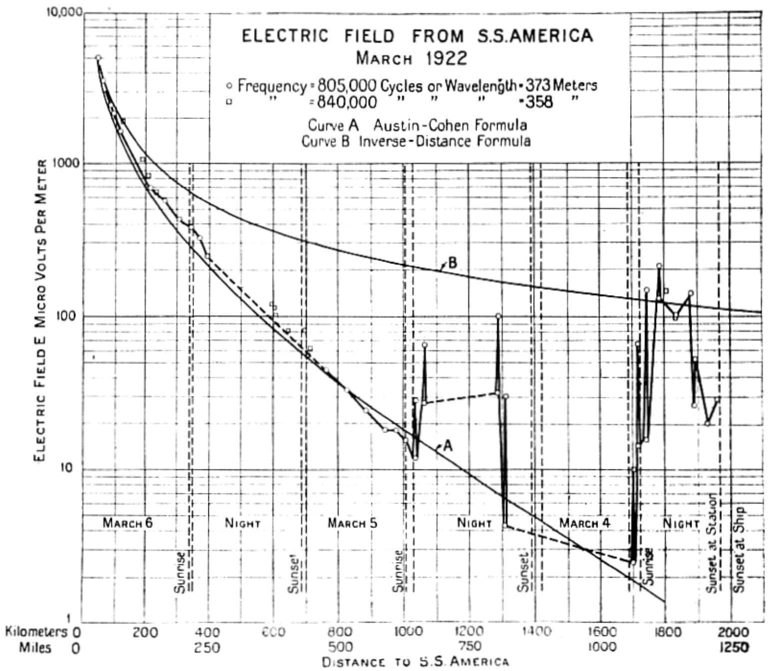


Fig. 20

(2) The wide fluctuations which occur thruout the night period. Altho smaller than the day to night fluctuations, their effect upon transmission is still very large. The fluctuations during the third night out, for example, are as much as 10:1 in field strength or 100:1 in power, or about 20 of the power ratio units we have used above. In view of the rapidity with which these fluctuations occur—within a very few minutes—it is practically impossible to maintain a circuit under these conditions satisfactory for regular telephone service.

(3) The most interesting thing to observe is that the fluctuations tend to fall within the two curves A and B. The day trans-

mission is a pretty definite proposition, following closely the Austin-Cohen formula. The night transmission appears in the nature of a "bob-up" from the day condition but seems to be limited in the extent of its "come-back" by the loss imposed by the simple inverse-with-distance law. The fact that the difference between curves A and B is entirely one of absorption suggests that the very large and rapid night fluctuations, which are now so well known to broadcast listeners, may be explained in large part if not in whole, by variations in atmospheric absorption.

Occasional Long Distance Transmissions

Many of the long distance records which have been made on short waves and low power can be accounted for simply on this basis—that the absorption which ordinarily obtains during daylight has been temporarily wiped out. The way in which it is possible for the range to "open up" tremendously under exceptionally favorable conditions will be seen from this: Referring to Fig. 20, assume that the normal daylight range between S. S. *America* and New York was 250 miles (400 km.) as fixed by a limit taken as 200 micro-volts per meter. Then, at night, this same field strength may be delivered over a distance of about 700 miles (1,100 km.) if the absorption is wiped out in accordance with curve B.

Furthermore, so favorable is the simple spreading-out law at such distances, that the field strength is only halved in going another 700 miles to 1,400 miles (2,200 km.) and only halved again in doubling this distance to 2,800 miles (4,500 km.), and so on. In other words under no-absorption conditions, by increasing the receiving radio frequency amplification by a current ratio of only $\frac{1}{2}\times\frac{1}{2}=\frac{1}{4}$, or about 12 power radio units, the range of transmission may be increased from the reliable daylight range of 250 miles (400 km.) to a possible night range of ten times this distance. It is therefore seen that many if not all of the long distance transmissions which have been realized for short periods of time probably can be explained simply on the basis of there having occurred an exceptional clearing up of absorption at a time of unusually favorable interference conditions.

Setting Up and Operating Combined Radio-Wire Circuits

The operating problems presented by the combination wire-radio telephone system are more difficult than those involved in the operation of either a straight telephone toll line on the one hand or the ordinary radio-telegraph circuit on the other. In regular long distance telephone circuits we have a fixed type of system which is maintained continually in good talking condition and the operators turn the terminals over to the use of the subscribers themselves. On the other hand in a radio telegraph circuit operating between land and vessel the circuit is kept entirely in the hands of skilled operators who have access to the apparatus and who handle the traffic directly between themselves. In no case before have we had the requirement of taking a radio link of varying length, building it up as occasion

SETTING UP A TELEPHONE CONNECTION

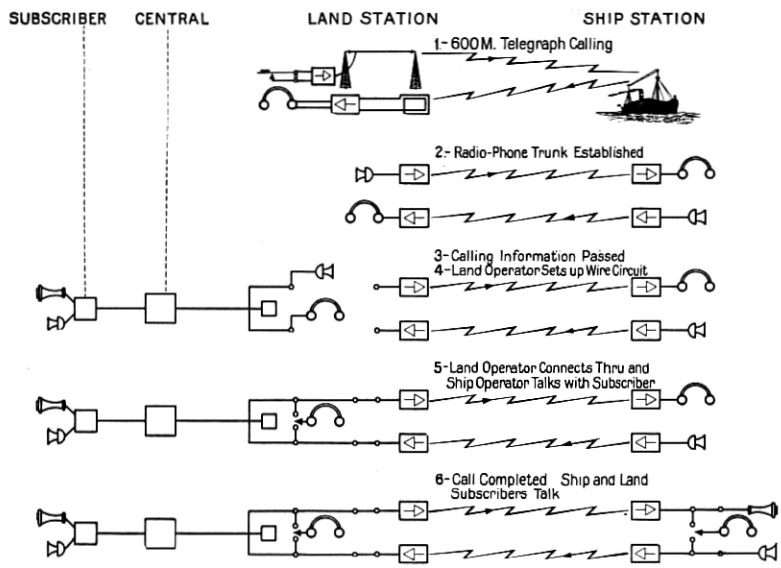


Fig. 21

requires with wire circuits and, upon call, putting the combined system at the disposal of people experienced only in the use of the regular telephone. The technical difficulties of the combination system, together with the necessity of coming as close as possible to meeting telephone standards in the quality of talk given, greatly reduce the length of the radio link which can be used for a service as compared with those distances which can be spanned for short periods of time under the most favorable conditions. The effect which the requirement of reliability has in reducing the range of transmission will be appreciated from the discussion of field strength measurements.

There are various ways in which the combination circuit can be set up and operated and it will take further experience before the most satisfactory arrangement is determined upon. In order to explain the operation generally, however, we will describe how the circuit was actually set up during the tests. Take the case of a call originating on the vessel; then the procedure is as illustrated in Fig. 21, namely:

1. When the ship comes within range she calls the land station by telegraph on 600 meters, and informs the land station of her message business.
2. The land station then assigns a pair of telephone channels to which both stations switch over and the circuit tested out for talking. In case of important long distance land line connection, this test may involve circuit transmission measurements.
3. The ship operator then passes to the land operator by voice (or by tone modulation telegraph) the information as to the connection desired.
4. The land operator then tells the ship operator to stand by while he switches to the wire circuit and passes the call to the telephone central, who in the case of a local call is a local operator (actually, for this case, she was the operator on the Cortlandt Official Board of the American Telephone and Telegraph Company at New York; or in the case of a long distance call is a toll operator.
5. The land line connection is made in the usual way and the shore station radio operator greets the land line subscribers.
6. The shore station operator then joins together the land line and the radio link thus connecting the land subscriber with the ship operator, who proceeds to tell the subscriber that this is the steamship so and so and that Mr. Blank wishes to talk with him. While this is going on, the land operator is monitoring on the circuit and makes such final adjustments of the amplification as may be necessary.
7. The ship operator then summons the ship subscriber and the latter takes up the conversation.

The handling of calls originated by the land line subscriber presents a more difficult operating problem because of the uncertainty as to the radio link—it not being known whether it can be established and, if so, as to how long a wait will be involved in getting the connection. During the tests, most of the calls originated in New York area. For these cases the land subscriber was connected to the Deal Beach station and there the call was put thru directly to the ship in case the radio telephone circuit was available. When not available, information as to the call was recorded by the radio operator and the telephone circuit released for the time being. The call was then completed by first setting up the radio link and then calling back the initiating subscriber. It is obvious that the giving of commercial service will involve: first, the ascertaining of whether or not the vessel is within range; second, the "lining up" of the radio link preparatory to the thru connection; and third, the building up of the land line connection back to the calling subscriber and the making of the thru connection. Many detailed variations are possible in the procedure and the determination of the best operating methods will have to await upon experience obtained in actually giving service.

Date 1/9/21 Station K Q G No. 4

Time ~~filed or~~ received 3:50 P.M.

FROM

Place NEWARK, N.J.
Tel No. 7522 WAVERLY
Person E.E.FREY

TO

Place S.S.GLOUCESTER
Tel. No.
Person M.E.FULTZ

Time Passed

Time land subscriber connected to ship operator 3:55 P.M.

Time circuit completed 3:55 P.M.

Time disconnected 3:58 P.M.

Reports QUALITY FAIR
VOLUME WEAK

Connection failed due to

Date 1/9/21 Station 2 X J 4 No. 4 (12)

Time filed ~~or received~~ 3:48 P.M.

FROM

Place NEWARK, N.J.
Tel No. 7522 WAVERLY
Person E.E.FREY

TO

Place S.S.GLOUCESTER
Tel. No. K Q G
Person M.E.FULTZ

Time Passed 3:50 P.M.

Time land subscriber connected to ship operator 3:55 P.M.

Time circuit completed 3:55 P.M.

Time disconnected 3:58 P.M.

Reports FAIR QUALITY

Connection failed due to

Fig. 22

In order to become familiar with the problems involved in maintaining the ship-to-shore system in operation, a series of operating tests were carried out for a period of about three months, starting in January, 1921, and operating between Deal Beach station and the S. S. *Gloucester*. In accordance with a pre-arranged schedule (unknown to the engineer-operators), calls were entered by a considerable number of Bell System engineers in the vicinity of New York, and calls were initiated from the vessels also by the opening of sealed envelopes carrying instructions to call one or more parties on shore. Fig. 22 is a facsimile of the message form or "ticket" used in the operating tests. The table below gives a representative record sheet recording the calls which were made on a partciular day and also the time which elapsed in putting each one thru. These data, of course, are not especially representative of what can be done with a system after it has begun smoothly in commercial service, but are interesting in giving a general idea of the way the system worked and in showing that calls were successfully put thru in a reasonably short time. In the aggregate a large number of calls were made, and as a result the system was put to a fairly severe operating test. It was found, as was to be expected, that the time required to put thru the

THREE CHANNEL OPERATION

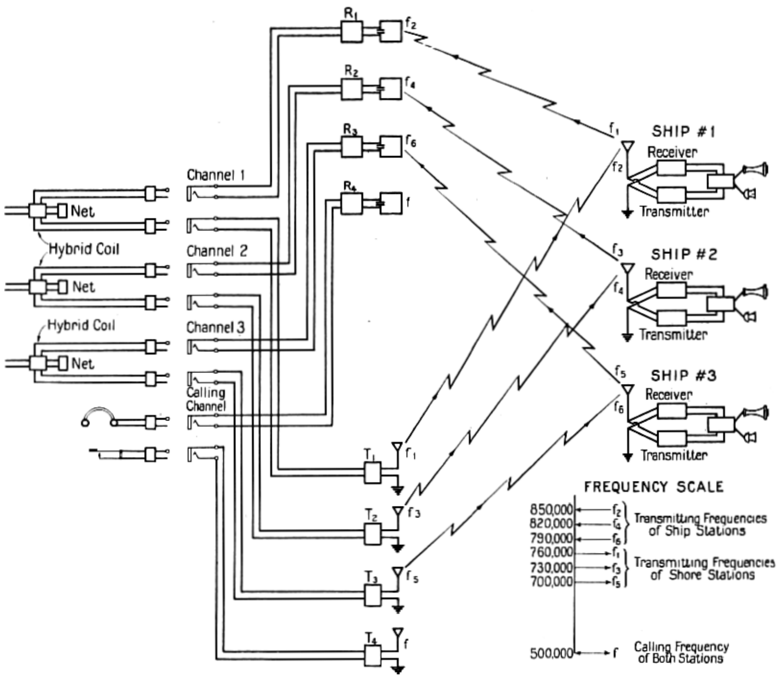


Fig. 23

radio connections to the vessels is large in comparison with the connecting time on the wire lines, and will require that precaution to be taken in the operating routine to minimize the time during which wire circuits are held up pending connection with the radio link. (The wire circuits used in the tests appeared in New York on a busy P.B.X. (private branch exchange) and did not receive the operating attention that they would in regular service.) But even tho the radio holding time was larger than the usual wire time, it is in itself rather surprisingly good considering the difficulties which attended this maiden operation of telephone circuits to ships and must be regarded as full of promise for the extension of telephone service to the highways of the sea.

Tests of Three-Channel Operation

Of course, any comprehensive ship-to-shore radio telephone system must be capable of establishing a number of telephone connections from a common land station to a number of ships. The Deal Beach experiments, therefore, had as one of their objectives the trying out of multi-channel operation. These tests were conducted during the fall of 1920 and thru January, 1921, with the S. S. *Gloucester* and the S. S. *Ontario*. A third boat was simulated by a small-power experimental set installed at the Cliffwood, New Jersey, experimental station. The three channel operation is illustrated diagrammatically in Fig. 23, which also shows the scheme of frequencies. The three channels transmitting from Deal Beach were grouped in one frequency range, spaced 30,000 cycles apart. The frequencies transmitted from the ships and received at Deal Beach were grouped in another frequency range removed 30,000 cycles from the first and having frequency intervals likewise of 30,000 cycles. Transmitting and receiving channels differing by 90,000 cycles were paired in the manner indicated to form two-way circuits. While it is possible to squeeze channels together more closely than this, it was not desired on the experiments to go to the limit of frequency squeezing, particularly because of the severe selectivity requirements imposed upon vessel equipment. These frequencies represented a fair balance between technical perfection on the one hand and practically realizable conditions on the other. It will be seen that the set-up was really a four-channel system, with the fourth channel used on 600 meters for calling purposes. Under these conditions three conversations were carried on successfully from the single land station, two to actual ships and one to a "dummy" ship at the Cliffwood experimental station.

Equipping of S. S. "America"

The primary development work of the ship-to-shore system was carried out, as described above, in conjunction with coastal vessels. Such vessels were chosen because the rapidity of their turn-round gave much more frequent test periods than could be obtained by means of vessels pursuing a longer route. It remained, however, to equip a trans-oceanic vessel and connect her into the telephone system.

In 1921, the development tests of ship-to-shore telephony were extended to include the General Electric Company and the Radio

Corporation of America. The engineers of these companies built a ship set similar to that developed in the work described above, but of a more commercial design, and installed in on the S. S. *America* in January. 1922.[4] During the succeeding few months, tests were made between the S. S. *America* and the shore, and on a number of these trips connections were put up to various interested parties around New York when the ship was within about 300 miles (480 km.) of the Deal Beach station. Of course, the *America* was carried out much farther than this at night, but the circuits were not sufficiently reliable to be used in connection with the land lines as will be appreciated from the field strength measurements given above.

A photograph of a portion of the installation on the S. S. *America* is reproduced in Fig. 9 above. The talking tests made with the *America* were the occasion of much interest on the part of the listeners-in, and several of the demonstrations which were given the subject of newspaper accounts and need not be described. The more technical phases of the tests with the S. S. *America* are (a) the field strength measurements, and (b) the simultaneous telegraph tests discussed below.

Simultaneous Telephone and Telegraph Operation Between Ship and Shore

During the experiments with the Steamships *Gloucester* and *Ontario*, the radio telephone transmissions were carried on alternately with the conduct of the regular radio telegraph service of the vessels. Simultaneous operation was impossible because the vessels were equipped with spark transmitters. While this arrangement of having to switch between either telephone and telegraph operation is permissible for small vessels where the communication load is light, it is, of course, not satisfactory for large trans-oceanic vessels where the message business may be such as to require practically continuous operation on the part of both services.

Recognizing, therefore, that one of the problems attending the successful application of radio telephony to large vessels is that of simultaneous telephone and telegraph operation, tests of such transmission were conducted in co-operation with the Radio Corporation of America from the S. S. *America*. These were made during February and March of 1922. On the land ends, the two radio circuits terminated at different stations, the telegraph at the Bush Ter-

[4] See article "Duplex Radio Telephone Transmitter," by Baker and Byrnes. *General Electrical Review*, August, 1922.

minal, New York City station of the Radio Corporation, and the telephone at our Deal Beach, New Jersey, station. The telegraph transmitter was of the continuous wave, vacuum tube type manufactured by the General Electric Company. The telephone and telegraph sets used individual antennas on the ship.

Altho certain apparatus difficulties were experienced aboard the vessel because of the short notice at which the tests were made, nevertheless the tests were successful and demonstrated that a telephone set can be made to operate simultaneously with a suitable C. W. (continuous wave) telegraph transmitter. The final solution of this problem of simultaneous operation, however, will undoubtedly require further work in co-ordinating the two types of systems, in order to permit them to be operated on wave lengths relatively close together. During the tests, the wave lengths were widely different, the telegraph operating on about 2,100 meters and the telephone on about 375 meters. The work done at Deal Beach in the development of multiplex telephone operation, where three telephone channels were operated in the vicinity of 400 meters and a fourth channel was operated for telegraphy at 600 meters, demonstrates that it should be feasible to operate telephone and telegraph channels simultaneously on closely adjacent wave length bands. However, in determining wave length allocations, these limiting factors will have to be considered: first, the greater susceptibility of the telephone to interfering noises, such as beat tones, and second the fact that the telephone requires two bands one for each direction of transmission and that these bands are required to be spaced a little apart in frequency. It is obvious that by controlling both types of channels from the same station they can be better co-ordinated in respect to frequency and general service use than if operated from separate stations, so that combined telephone-telegraph shore stations present interesting possibilities for the future.

Another method of operation, and one which requires fewer wave lengths, is that of superimposing the telephone and telegraph channel on the same carrier wave after the general manner of compositing long distance telephone lines with telegraph. This can be done by combining the two channels on one circuit as is done in wire practice and then modulating the combined channels upon the radio carrier. At the receiving end both channels can be detected simultaneously and then the channels separated by composite sets or filters. This method is mentioned to show the ultimate possibilities of combined operation and is not put forward as one which is sufficiently practical, all things considered, for use in the art of the immediate future.

Radio Linked with Transcontinental Line and Catalina Island

The ship-to-shore radio link was on several occasions connected with very long distance circuits in order to demonstrate the extreme conditions under which combined radio and wire operation are possible.

Perhaps the most interesting case is that in which the ship was linked up with the transcontinental telephone line and connected thru to Catalina Island in the Pacific thus bringing together the two oceans. The circuit arrangements for one of these demonstrations are given schematically in Fig. 24. Both the Deal Beach and Green

TRANSCONTINENTAL LINE WITH RADIO EXTENSIONS

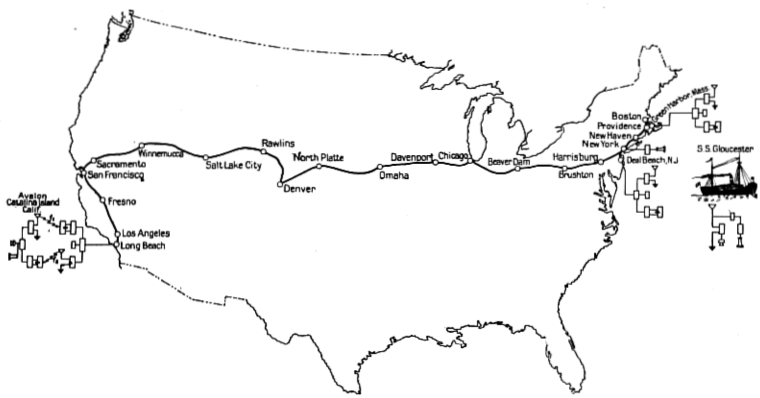


Fig. 24

Harbor shore stations were used, since it was desired to reach the ship anywhere on her course from Boston to the Delaware capes. The demonstration was, therefore, also an example of connecting the ship into the land telephone system thru either of two shore stations. As a matter of fact, at one time the vessel could be reached thru both stations. It happened that the vessel was coming up the coast. The night before the demonstration the ship was communicated with thru the Deal Beach station and connected thru to Catalina Island for a rehearsal. For the demonstration of the following morning, connection was made thru Green Harbor. During both the rehearsal and the demonstration the operator on the vessel talked successfully, altho with some difficulty, with the Catalina Island operator, while New York listened in. This demonstration was made for General J. J. Carty on February 14, 1921. An earlier demonstration of a similar nature, although not involving Green Harbor, was made for the delegates of the Preliminary International Communications Conference on October 21, 1920.

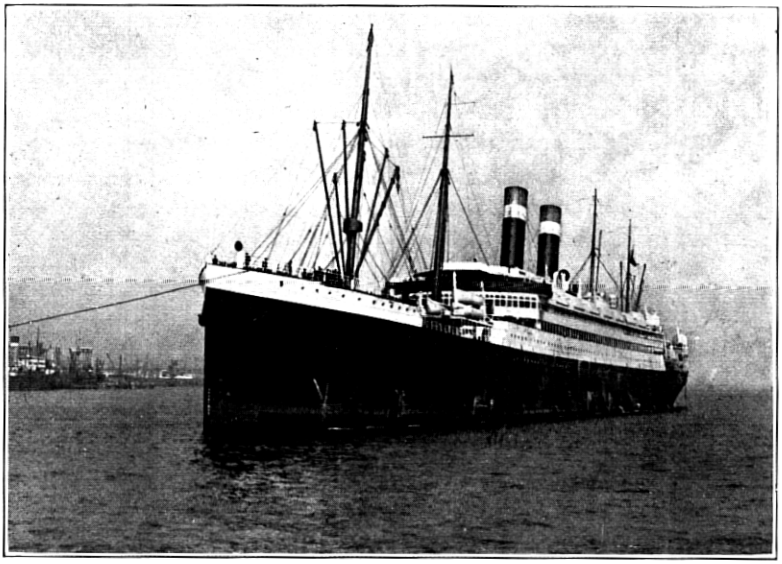


Fig. 25

Conclusions

The results of this development may be summed up as follows:

(1) It has realized a radio-telephone system capable of giving two-way transmission and meeting the requirements imposed by joint radio-wire operation.

(2) It has demonstrated the actual use of this radio-telephone system in a wire-radio toll circuit as a means for extending the telephone service of the country to include vessels at sea.

(3) The experiments have demonstrated also the practicability of multi-channel operation from a common land station whereby a number of land subscribers may be connected simultaneously to a number of different vessels.

(4) The transmission and operating tests show the difficulties attending the establishment and maintenance of the radio-telephone link to a moving vessel and the necessity for careful

adjustment of the transmission conditions of the circuit and for a diligent maintenance of these adjustments during operation.

(5) In the experiments in multi-channel operation and in simultaneous telephone and telegraph transmission from the same vessel, a beginning has been made in one of the most important problems concerned with the early application of radio telephony to the marine service, namely, that of the co-ordination between radio-telegraph and radio-telephone transmission. It is obvious that the general development of the art of selective transmission, as well as the entrance of radio telephony, calls for the use of purer carrier waves and of a minimum transmission band in radio telegraphy.

(6) As regards the important question of wave lengths, the development has shown that the relatively short waves employed in the experiments are satisfactory up to several hundred miles but that for longer distances longer wave lengths will be required. The difficulty of obtaining for the marine service a wave length sufficiently wide for permitting the handling of any considerable traffic is obvious. The band which can be allocated to this service will naturally be limited by the requirements of other services; and the intensiveness with which this band can be worked by closing up the frequency spacing between channels is limited by the consideration of intercommunication between different types of systems and by apparatus expense.

In general it may be said that the present development has contributed to the communication art the means whereby the universal land line telephone system may be extended to ships at sea. The actual giving of such service must await the working out of the economic problems involved and the necessary business and organization arrangements between the communication companies and the steamship companies.

DAILY RECORD SHEET

Ship to Shore Radio Service

System Test

April 6, 1921.

TELEPHONE CALLS

		Destination	Total time to connect (hr. min.)	Delayed	Interruptions	Cancelled	Completed Unsatisfactory	Completed Satisfactory	Remarks
From ship	1	N.Y.	41					✓	Good.
	2	N.Y.	37					✓	Good.
	3	N.Y.	16					✓	Good. Weak arc QRM.
	4	N.Y.	4					✓	Fair, (weak) bad arc QRM.
	5	Newark	3 - 53	P. (11.55 A.M. Out till P.M. (2.14 P.M. Still out.				✓	Good, (weak QRM, spk.)
	6	Long Branch	3 - 01	P. (11.53 A.M. Don't. ans. (2.13 P.M. Answ'd. Party out.				✓	Good, but weak.
	7	Asbury Park	2 40	P. 2.19 P.M. Out.				✓	Fair. QRM from 3[illegible].
	8	N.Y.	22					✓	Good.
	9	Newark	36	P. 3.00 P.M. Out of Bldg.				✓	Good, but weak.
	10	Asbury Park	-			3.47 P.M. Out till 5 P.M.			
	11	Newark	15					✓	Good. Quite noisy.
	12	N.Y.	50					✓	Good. Spk. QRM.
	13	Allenhurst, NJ	57					✓	Good. Weak QRM, 3 QM.
	14	Asbury Park	29					✓	Good. (Bad spark QRM)
To ship	1	N.Y.C.	21					✓	Good.
	2	N.Y.C.	45					✓	Good. Ship has spark QRM.
	3	N.Y.C.	53					✓	Fair.
	4	N.Y.C.	47					✓	Fair.
	5	N.Y.C.	-			10.44 A.M; 3.43 P.M; don't ans.			
	6	N.Y.C.	19					✓	Good.
	7	N.Y.C.	11					✓	Good.
	8	N.Y.C.	12					✓	Good, Mr. Maxfield tries out transmitters.
	9	Spring Lake	18					✓	Good.
	10	N.Y.C.	20					✓	Good.
	11	N.Y.C.	03	P. (2.15 P.M. Not in. (2.30 P.M. Will Call.				✓	Good.
	12	N.Y.C.	3					✓	Fair.
	13	N.Y.C.	-			3.02 P.M. Not there today.			
	14	N.Y.C.	26	P. 3.30 P.M. Line busy.				✓	Fair.
	15	N.Y.C.	18		E. 3.50-3.51 P.M. Cut off.			✓	Fair.
	16	N.Y.C.	9					✓	Fair.
	17	N.Y.C.	25					✓	Fair.

TELEGRAMS

		No. of words	Total time to transmit	Actual time to transmit	Delay to telephone service
From ship	1				
To ship	1	114	13	8	0
	2	17	4	1	0

SUMMARY

Total calls	31
Completed	28
Cancelled	3
Long Distance	0
Toll	1
Local	30

Calls completed and satisfactory	28	90.3%
Calls completed and unsatisfactory	0	
Calls cancelled due to system failure	0	
Calls cancelled not due to system failure	3	9.7%
		100.

Average time

Radio A	13.6 mins.
" B	.16 "
Wire A	8.0 "
" B	0

$$\frac{\text{Total minutes operation}}{\text{Total calls}} = \frac{551}{31} = 17.7$$