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OPERATION OF A SHIP-SHORE RADIOTELEPHONE SYSTEM*

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Summary—*During the past two years, ship-shore radiotelephone service has been available with several of the large transatlantic liners. This service has been fairly reliable over distances up to about halfway across the Atlantic and some measure of service has been available all the way across. This paper reviews the essential physical and operating features of the land and ship terminals employed in giving this service.*

Problems encountered in establishing and operating this service are discussed, together with measures applied for their solution. The most difficult problems have arisen in connection with adapting the ship terminal for operation under the limited space conditions encountered on shipboard. These conditions impose undesirable proximities between units of equipment and between antennas.

The operating plan used in coördinating the establishment of the contacts between ship and shore stations is discussed.

Considerable data have been collected during the past two years incidental to the operation of the system. Of interest are the contour diagrams indicating the variation of signal fields with time of day and with distance.

The variations of the grades of circuit at various distances obtained as a result of operation are shown. During the first six months of 1931, commercial grades of circuit were obtained in about 85 per cent of the contacts.

I. Introduction

REGULAR ship-shore radiotelephone service with several of the large passenger vessels plying the North Atlantic has been available for nearly two years. At the present time the vessels equipped for this service are the steamships Leviathan, Majestic, Olympic, Homeric, Belgenland, and the Empress of Britain. On the American side the service is handled through the radio stations of the American Telephone and Telegraph Company and on the European side through the stations of the British General Post Office. Previous papers[1,2,3,4] have discussed the terminal arrangements, particularly on shore, and the general ship-shore plan more or less in detail. After reviewing these

* Decimal classification: R412×R510. Original manuscript received by the Institute, October 1, 1931.

[1] W. Wilson and L. Espenschied, "Radiotelephone service to ships at sea," *Bell Sys. Tech. Jour.*, July, 1930.

[2] A. S. Angwin, "Ship and shore terminal equipment," *Electrical Communication*, July, 1930.

[3] A. G. Lee, "Radio communication services of British Post Office," Proc. I.R.E., October, 1930.

[4] Miller, Bown, Oswald, and Cowan, Papers on "Transoceanic Telephone Service," *Trans. A.I.E.E.*, April, 1930.

terminal arrangements briefly, the present paper will concern itself with the general plan of operation and some of the results which have been obtained.

The steps in providing this ship-shore radiotelephone service have involved:

1. For the shore, essential duplication of the radio transmitting and receiving and voice-frequency terminal equipment of the short-wave point-to-point services such as the New York-London and New York-Buenos Aires services.
2. For the ship, provision of suitable radio transmitting and receiving equipment—either new or adapted—and overcoming the difficulties of two-way operation under conditions of small physical separation between the radiotelephone transmitter and receiver, and also between the radiotelephone and radiotelegraph equipment—which should preferably be able to work simultaneously.
3. Selection of several frequencies for radio transmission permitting coverage of the entire North Atlantic Ocean.
4. Development of an operating plan involving minimum delay in clearing traffic and at the same time providing for operation with both American and European shore terminals.

II. Circuit Set-up

A general picture of a ship-shore radiotelephone circuit is shown in Fig. 1.[1] It will be noted that the circuit consists really of two separate one-way channels between the ship subscriber and the control position in New York City, where, in conjunction with special apparatus, the two channels are united and connected to the regular wire telephone plant, eventually reaching the shore telephone subscriber.

Ship Terminal

The details of the installations on the various ships differ somewhat because of their being supplied by different concerns.† In general, however, the equipments on the various ships are similar.

The radio transmitters supply from 500 to 1500 watts of radio-frequency power, modulated approximately 80 per cent, to simple vertical antennas as in the case of the Leviathan, to doublets as on the steamships Olympic, Majestic, and Belgenland, or to "Marconi Beam Ele-

[1] *Loc. cit.*

† Concerns supplying ship equipments as follows: The Marconi International Marine Communication Co. Ltd., Steamships Homeric and Empress of Britain; International Marine Radio Company Ltd., Steamships Belgenland, Olympic, and Majestic; American Telephone and Telegraph Co. (Bell Telephone Laboratories), Steamship Leviathan.

ment " antennas as on the steamships Homeric and Empress of Britain. Air-cooled tubes are used in the final radio stage on the steamships Leviathan, Homeric, and Empress of Britain while water-cooled tubes are used on the steamships Olympic, Majestic, and Belgenland.

The radio receivers are generally of the double detection type carefully shielded and with a high degree of selectivity for discrimination against interference from the carrier of the local radiotelephone transmitter and interference from the ship's telegraph transmitter.

The voice-frequency equipment comprises, in general, one amplifier in the transmitting channel, one in the receiving channel, adjustable

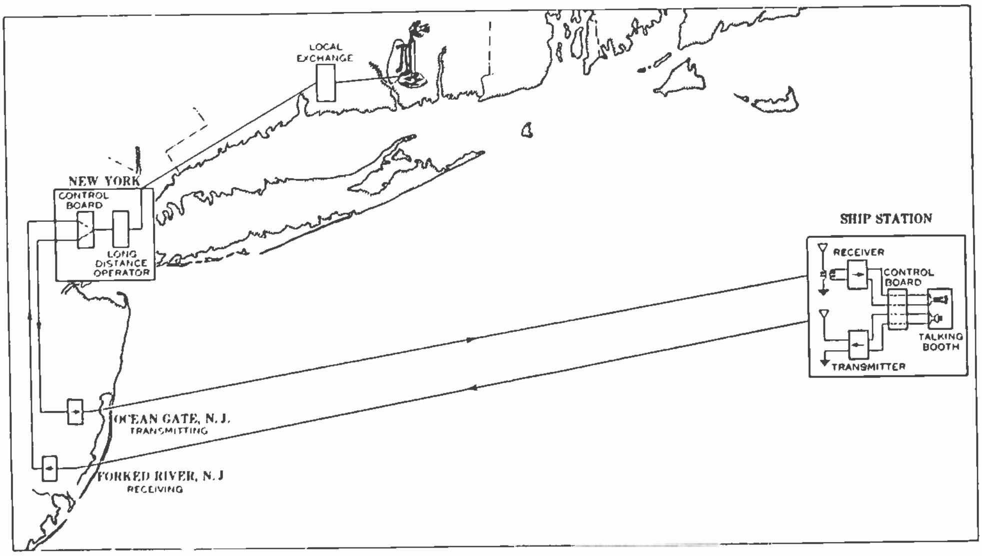

Fig. 1—General picture of ship-shore radiotelephone circuit.

gain controls to regulate both transmitted and received speech volumes, volume indicators, monitoring facilities and certain voice-operated devices which, when required, may be used to suppress the radio-frequency carrier when the ship subscriber is listening and to cut off the output of the ship receiver when the ship subscriber is talking. In most cases, the transmitting and receiving channels are kept separate throughout and terminate in a special (four-wire) telephone set in a small room, located close to the purser's office or in some other location convenient for the passengers, which is used as a telephone booth. Completing calls directly to the passengers' staterooms over the ship's wire telephone system can be provided for wherever warranted by using voice-operated devices similar to those employed at the shore terminal.

The conditions under which a ship radiotelephone system must operate differ considerably from those applying to a land station. On land, receiving sites can be selected which will be free from serious electrical interference and which are miles distant from the transmitting sites. On shipboard, on the other hand, the equipment itself must be compact and there are imposed conditions of inadequate physical separation not only between the telephone transmitter and receiver, but also between the telephone and the telegraph systems. Even on the larger ships, such as the Leviathan, the greatest separation which could conveniently be obtained between the telephone and telegraph or between the radio transmitters and receivers is only about 500 feet. Nevertheless, on the Leviathan, through coöperation of the telephone and telegraph staffs, three radiotelegraph services and the radiotelephone have been operated simultaneously.

In addition to telegraph interference, a serious problem has been that of interference of the ship's telephone transmitter with the ship's telephone reception. This interference is of two kinds:

1. Carrier from the ship's telephone transmitter may overload the radio receiver.
2. Carrier from the ship's telephone transmitter may induce radio-frequency currents in stays and other metallic parts of the ship. Variable contacts at points in these current paths serve as secondary sources of radio noise which is picked up in the radiotelephone receiver. This noise does not occur continuously but becomes particularly bad when the rigging is covered with wet salt spray and when vibration is excessive.

In addition to interference from the radio equipment aboard, it was found that electrical machinery, such as ventilator fan motors, elevators and hoists caused considerable noise. Although the method of reduction of interference from electrical machinery is straightforward, nevertheless on account of the large number of units involved, the job was by no means a small one.

There are two general methods of dealing with the interference between transmitters and receivers. The first is effective in reducing the interference from either the telephone or telegraph transmitter and consists in obtaining the maximum possible physical separation between the transmitters and the receiver, obtaining the maximum feasible frequency separation between transmitting and receiving channels, bonding of the stays, and other measures. The second method is effective only in so far as interference from the associated transmitting carrier is concerned and consists of suppressing the carrier when receiving.

From the standpoint of simultaneous operation of telephone and telegraph and the effect of local carrier and stay noise, the best arrangement would be to have all the radio transmitters—telephone and telegraph—grouped together and placed as far aft on the ship as is feasible (so as not to affect the radio compass) and to group all the radio receivers and place them as far forward as possible. Such an arrangement is, however, expensive to effect on ships which already have the telegraph equipment installed and have no special provision for radiotelephone.

The general arrangements of the radiotelephone equipment vary with the different ships. Excepting the Leviathan, the transmitter and the receiver are separated as far as practicable. In the case of the Leviathan, the radio transmitter and receiver are located in the same room to facilitate operation. The receiving antenna is about 75 feet aft of the radiotelephone room and is connected to it by means of a shielded transmission line. On all of the ships, the voice-frequency equipment is adjacent to the radio receiver. From this point the transmitting and receiving voice-frequency circuits extend to the subscriber's booth.

To prevent overloading of radio receivers from the transmitter carrier requires high selectivity in the receiving circuits, separation of the transmitting and receiving antennas, and a reasonable separation between the ship's transmitting frequency and the ship's receiving frequency. A minimum satisfactory frequency separation is considered to be about 3 per cent. To reduce the stay noise adequately requires a frequency separation of 5 or 6 per cent, or a physical separation of 300 feet or more. Welding or bonding the stays and packing the joints with graphite may also be helpful. The latter method is, however, expensive and there are usually some sources of disturbance which cannot be found, or that do not lend themselves to bonding. No simple permanent cure for this type of interference has yet been found.

The second method of overcoming trouble from stay noise and other effects of the local carrier, is to transmit the carrier only when modulated, that is, when the ship subscriber is talking. This is accomplished by use of a voice operated relay which removes an abnormal bias from either the primary oscillator or the radio-frequency amplifier when speech is being transmitted.

A system which necessitates cutting off the carrier, except when modulated, has certain disadvantages:

1. With automatic gain control at the shore receiver, the gain rises to a preadjusted maximum as soon as the ship subscriber stops talking, which brings up the received noise. This may not only be disconcerting to the shore subscriber, but may lock up the voice-operated devices on the receiving side at the shore control terminal, thereby preventing the shore subscriber from

talking out. To overcome this difficulty without sacrificing sensitivity and received volume involves the use of a carrier-operated device to cut off the voice-frequency output of the shore receiver when no carrier is being received from the ship.

2. During times when it is difficult to establish contact between the ship and the shore, it is not possible to have the ship leave its carrier on continuously and still monitor for the shore station. Even leaving the carrier on intermittently will delay the contact.

Notwithstanding its disadvantages, suppression of the carrier by voice-operated devices seems at present to afford about the simplest

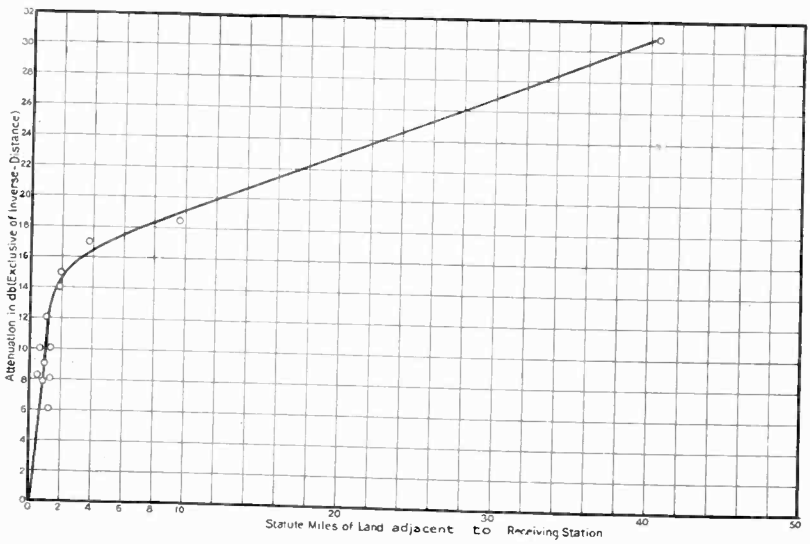

Fig. 2—Overland transmission on 4 mc from ships at sea. Measurements made at Forked River and vicinity, 1930.

way of avoiding the difficulties from stray noise and the overloading effect of the local carrier. All of the ships are now equipped for this method of operation whenever interference becomes sufficiently serious to warrant its use. At other times the system is operated without use of the carrier suppression relays.

The use of voice-operated devices to suppress the local carrier is, of course, not effective against interference produced by other telephone or telegraph transmitters on the ship and separation, both physical and in frequency, must be relied upon.

Shore Terminal

The shore radio transmitting and receiving stations are located at Ocean Gate and Forked River, New Jersey, respectively, about seven miles apart and about 60 miles south of New York on the New Jersey

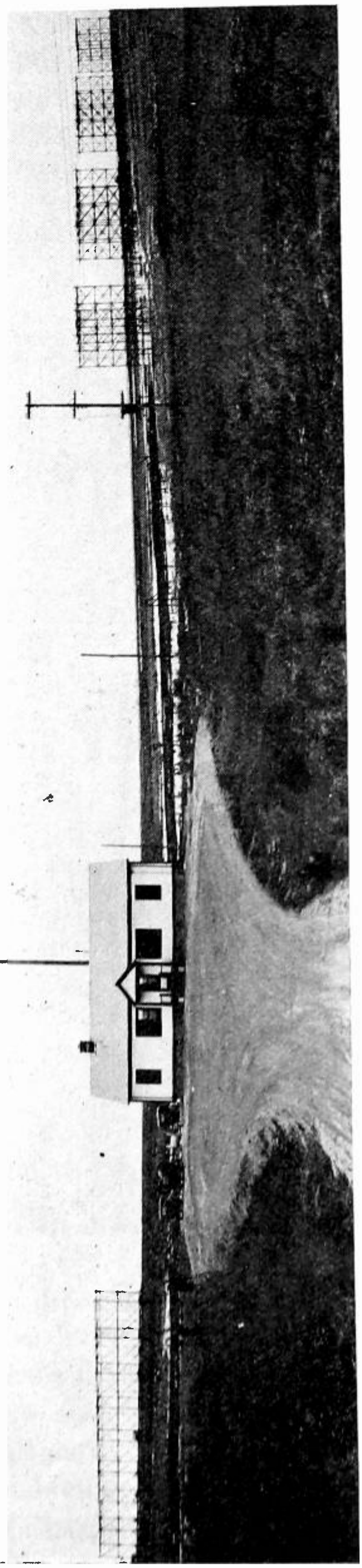

Fig. 3—Ship-shore radiotelephone receiving station at Forked River, New Jersey.

shore. The tract for the transmitting station is about 175 acres, and that for the receiving station, 377 acres. The location directly on the coast was the result of tests[5] indicating that overland attenuation of the ground wave, which is used for transmission out to distances of the order of 200 or 250 miles is quite high for even a small amount of land.

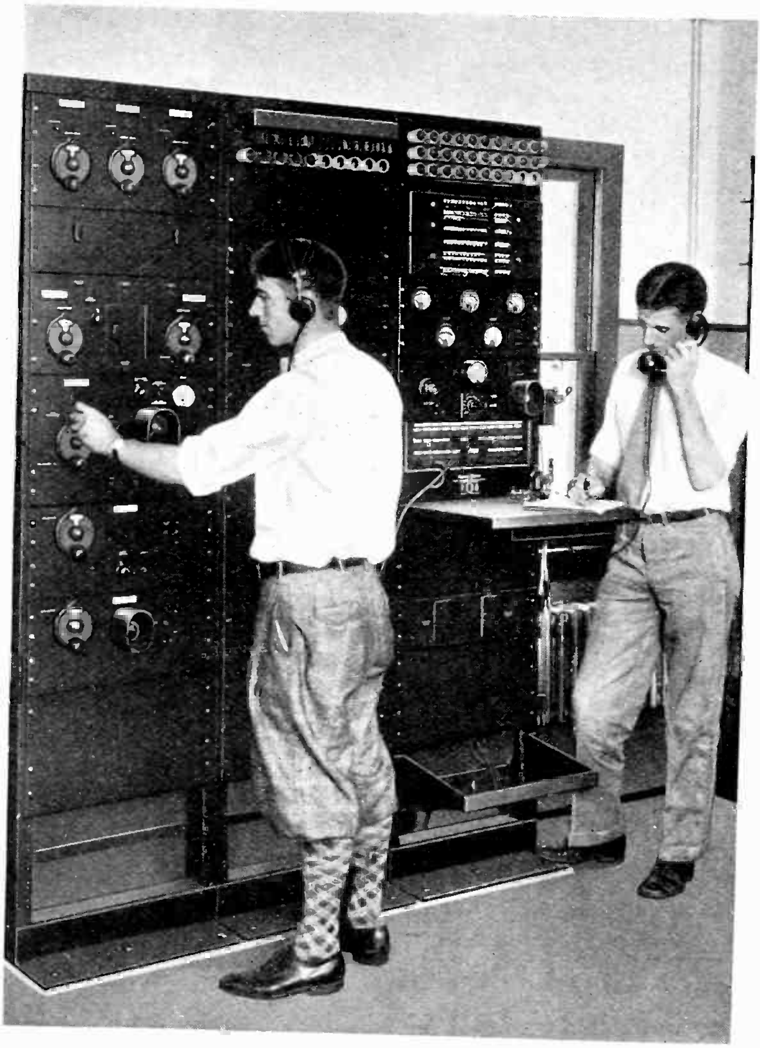

Fig. 4—Receiving set of a special type. This set is arranged to operate over a wide range of wavelengths and is provided with switching devices to permit connection to any one of several antennas.

A curve showing some results taken later at Forked River on 4392 kilocycles is shown in Fig. 2. This indicates that a mile of overland transmission results in 9 db less signal field strength than for transmission over one mile of water. Such a loss is equivalent to cutting down the

[5] R. A. Heising, "Effect of shore station location upon signals," Proc. I.R.E. 20, 77–87; January, 1932.

power radiated by the transmitter to one eighth. Except for the antennas, the shore stations are similar to those in use on the point-to-point services between New York and London and New York and Buenos Aires which have been described previously.[4]

The receiving station at Forked River with the 4-megacycle and 8-megacycle receiving arrays is shown in Fig. 3. For reception on 13 megacycles and 17 megacycles, a horizontal diamond shaped antenna is used.[6] The horizontal antenna is very effective in reducing interference from motor boat ignition systems, as this radiation appears to be largely vertically polarized. The radio receiver used is shown in Fig. 4 with a block schematic drawing in Fig. 5. As mentioned previously, a relay controlled indirectly by the carrier received from the ship, cuts

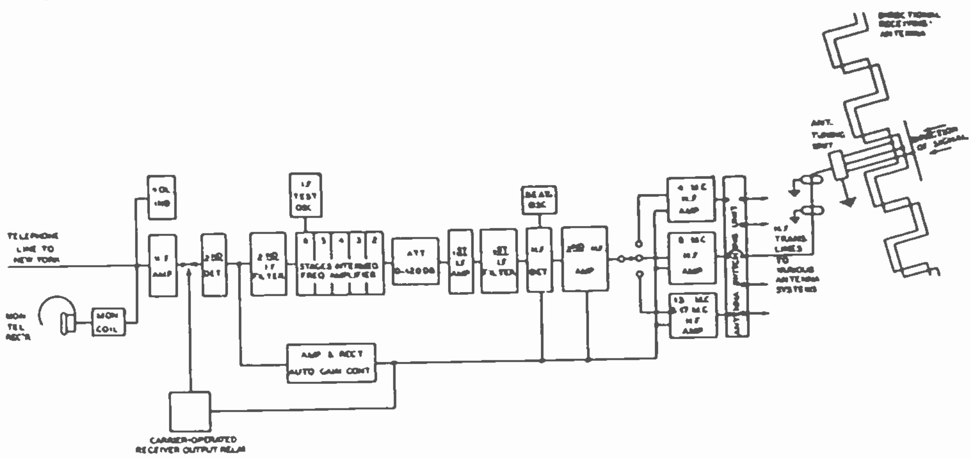

Fig. 5—Block schematic of radio receiving system at Forked River, New Jersey.
(1) Intermediate frequency filters adjusted to pass band 395 kc.
(2) Operation of carrier-operated receiver output relay is such that when a carrier is being received, the receiver output is "normal," but when no carrier is received, the output of the receiver is "cut off."

off the voice-frequency output of the shore receiver when the ship transmitting carrier is off. This prevents the high noise resulting from the increased receiver gain from being heard by the shore subscriber and simplifies the adjustments of the voice-operated relays at the control terminal. Several receivers are provided to permit monitoring on frequencies which are not being used at the moment for traffic, but on which some ship may call for a connection.

The radio transmitting station at Ocean Gate is pictured in Fig. 6. A view of the radio transmitter itself is shown in Fig. 7 with the corresponding block schematic diagram in Fig. 8. Because of the rather large geographical sector determined by the steamship lanes to which

[4] *Loc. cit.*
[6] E. Bruce, "Developments in short-wave directive antennas," PROC. I.R.E., August, 1931.

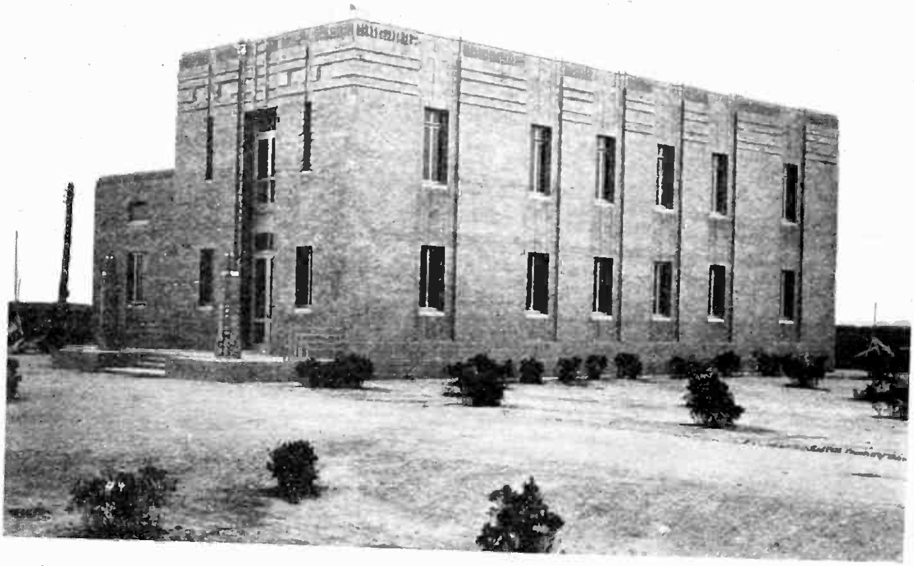

Fig. 6—Ship-shore transmitting building at Ocean Gate, New Jersey.

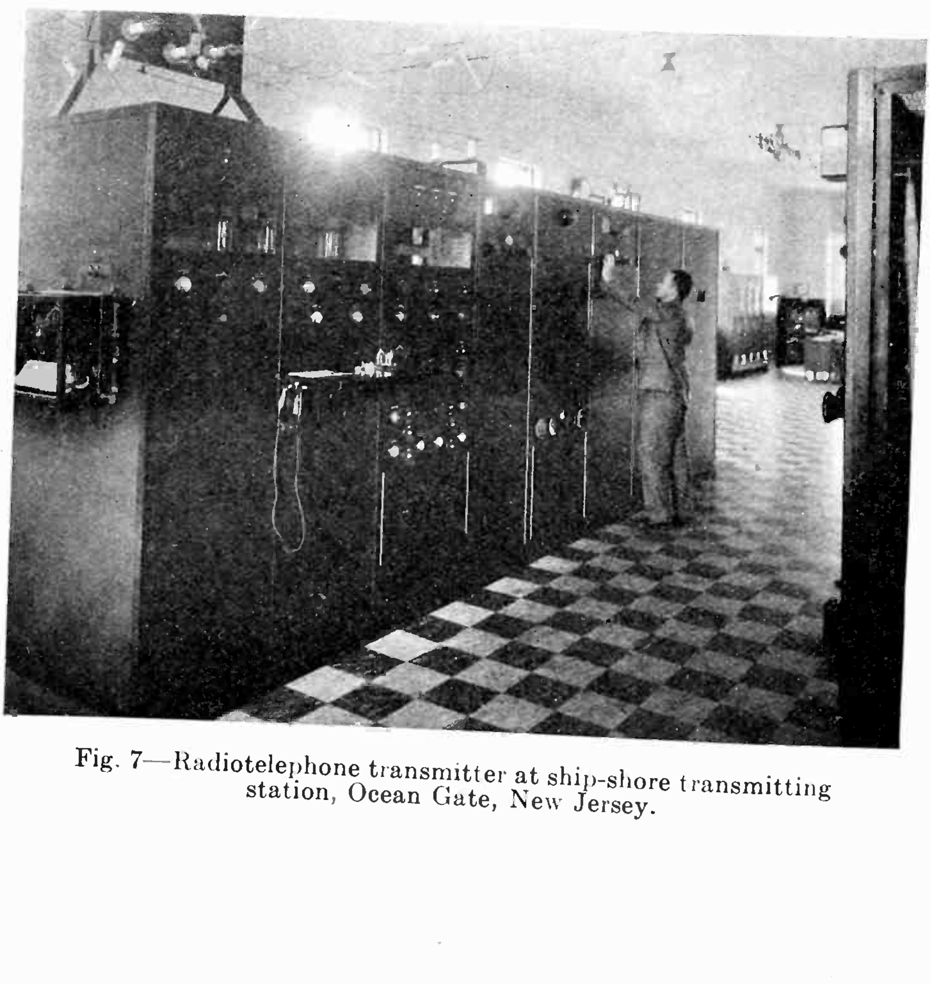

Fig. 7—Radiotelephone transmitter at ship-shore transmitting station, Ocean Gate, New Jersey.

service must be given (shown in Fig. 9) the antennas are not as directional as in point-to-point service nor are all the antennas directed in exactly the same direction, since they serve different regions. Two of

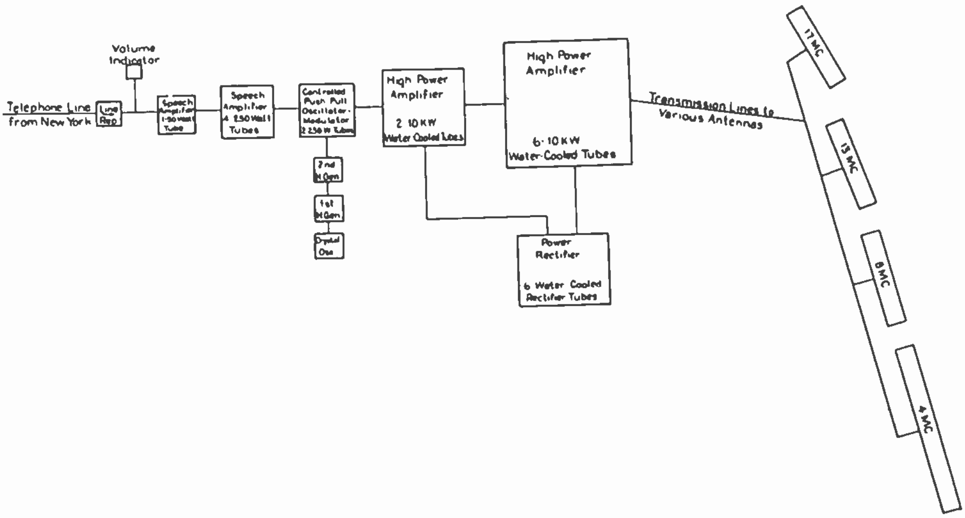

Fig. 8—Block schematic of radio transmitter at Ocean Gate, New Jersey.

the antennas (4 megacycles and 8 megacycles) are of the Bruce type, and two (13 megacycles and 17 megacycles) are of the saw-tooth type.

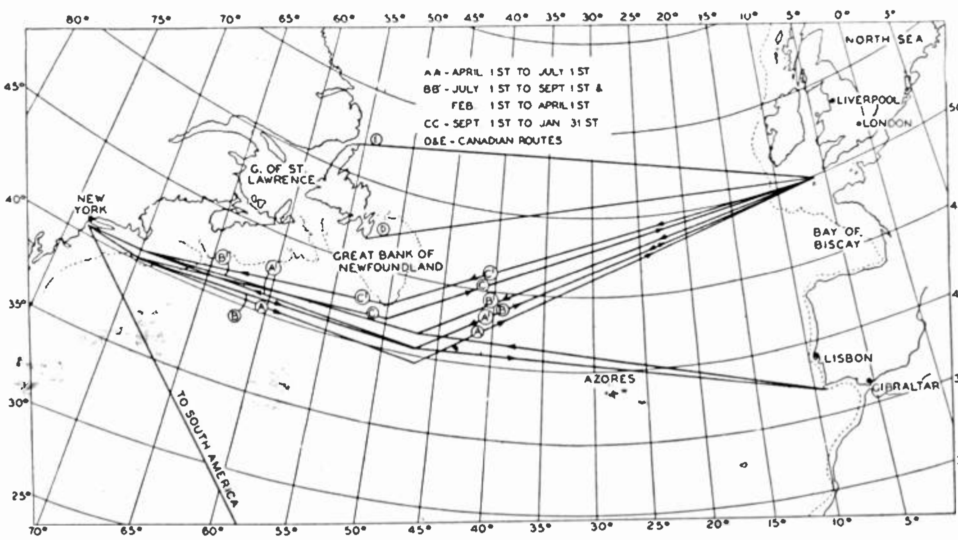

Fig. 9—North Atlantic Steamship lanes.

As indicated in Fig. 1, two pairs of conductors, one from the transmitting station and one from the receiving station, extend back to the ship-shore control position in New York.[7] This control position

[7] S. B. Wright and H. C. Silent, "The New York-London telephone circuit", *Bell Sys. Tech. Jour.*, October, 1927.

is one of the seven similar positions pictured in Fig. 10, and used for various Bell System radiotelephone facilities terminating in and around New York. Fig. 11 shows the block schematic of the control terminal. This equipment consists essentially of amplifiers, volume indicators

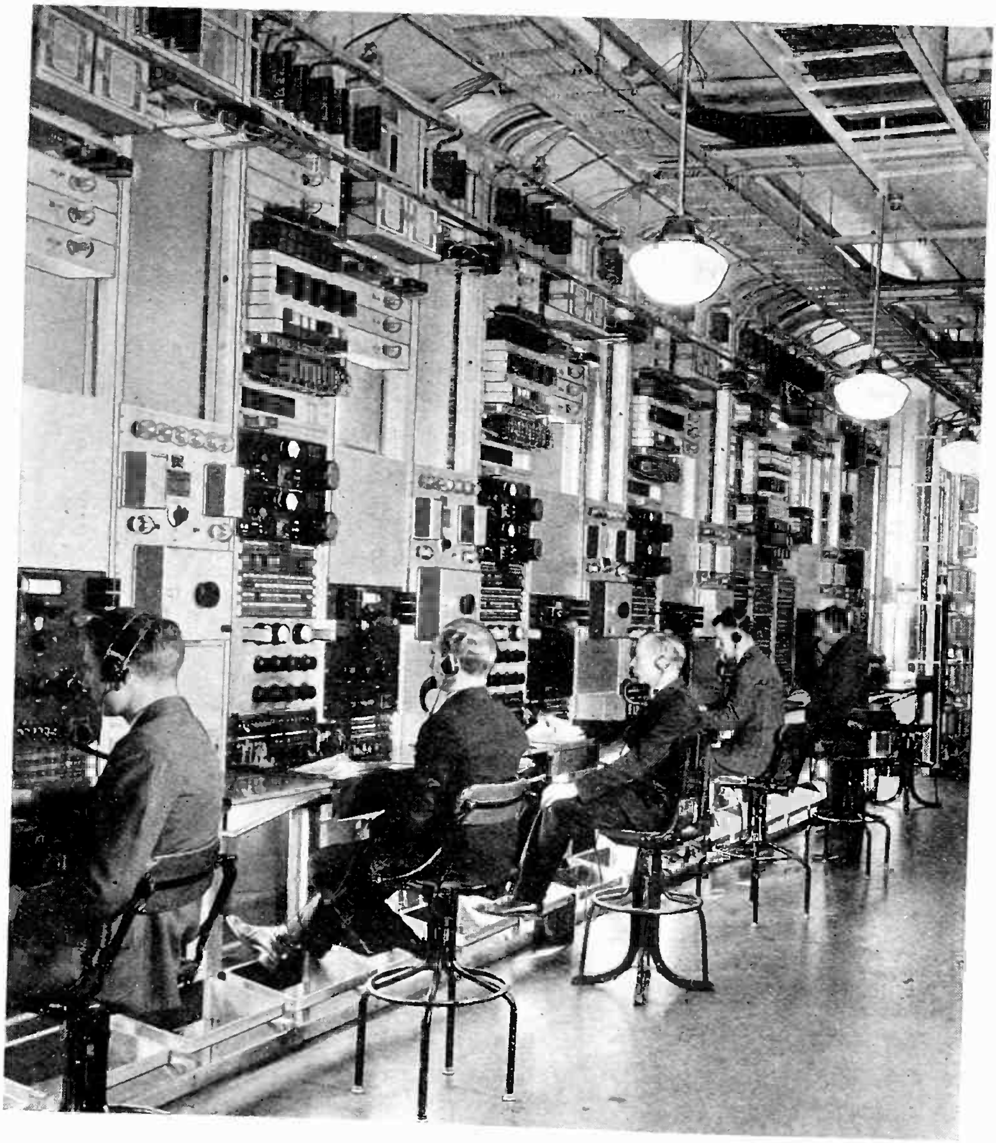

Fig. 10.

and gain controls for adjusting the receiving and transmitting speech volumes, a hybrid coil terminating set for combining the transmitting and receiving channels so as to enable the radiotelephone circuit to be connected into the regular wire telephone system, and, finally, the voice-operated relays with the associated equipment which automatically make the circuit one-way transmitting or receiving, depending on whether the shore subscriber or the ship subscriber is talking, and thereby eliminate echoes, singing, and reradiation of noise.

With no speech in either direction the positions of the voice-operated relays are such that the circuit is in receiving condition. When speech is received from the ship the transmitting relays are rendered inoperative by the receiving echo suppressor relay insuring that the transmitting branch will remain shorted and suppress echoes of the received speech which would otherwise be radiated from the radio transmitter. When the ship subscriber stops talking and the shore subscriber

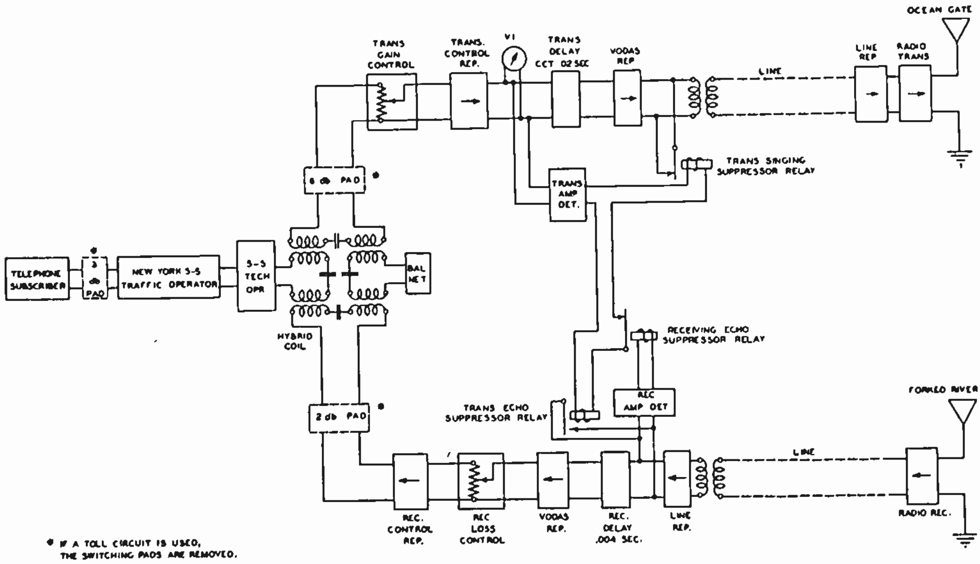

Fig. 11—Block schematic of control terminal and relation to radio stations and wire telephone system.

answers, the transmitting relays remove the short from the transmitting branch, permitting the speech to go on to the radio transmitter and at the same time disable the receiving branch and the receiving echo suppressor circuit. All these operations occur automatically and within a few thousandths of a second, so that they are unnoticed by the telephone subscriber.

From the technical operator's control position the circuit extends to the traffic operator's position (Fig. 12) which differs little from the ordinary toll traffic position, except in special monitoring facilities for timing the call and making proper allowances for repetitions or circuit interruptions, and so forth. At the traffic operator's position are facilities for reaching any one of 32,500,000 telephones, or over 90 per cent of the 35,000,000 telephones in the world.

III. Operating Plan

With shore stations and ships equipped for adequate transmission over the areas in which service was to be given and with provision made for extending the radio connections to the land telephone systems, there remained the problem of providing a satisfactory operating plan. This plan had to satisfy two general requirements:

1. Calls originating from or destined for ships anywhere in the North Atlantic should be completed with minimum delay.

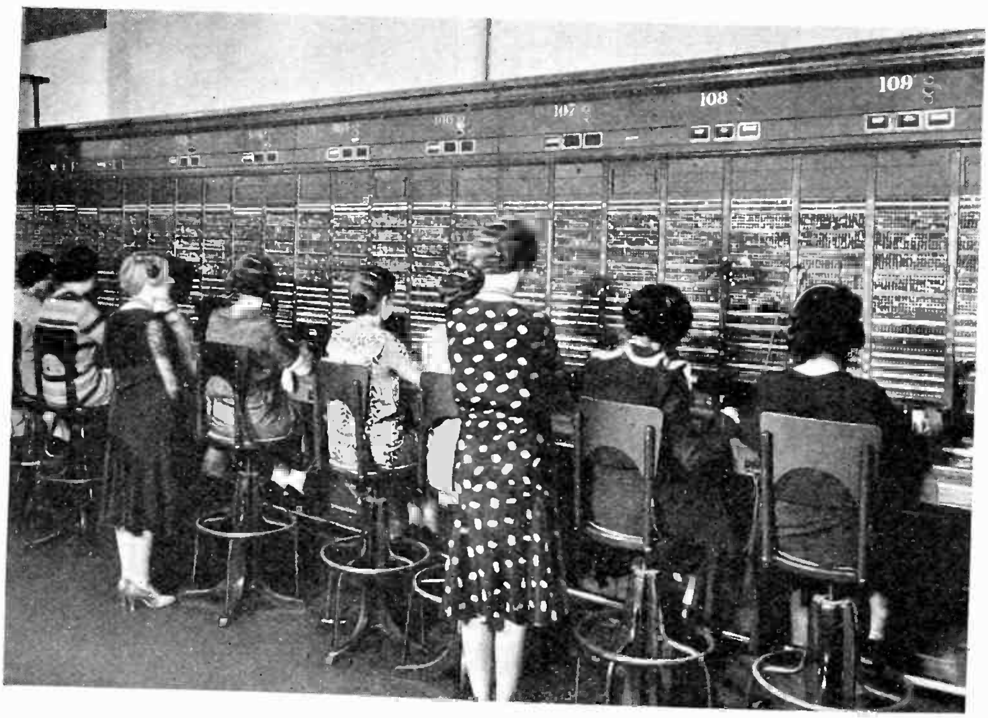

Fig. 12—Transoceanic and ship-shore traffic operating positions.

2. Provisions should be such that ships can work with both European and American shore stations.

Because of the desirability of keeping the ship transmitting and receiving frequencies separate, a pair of frequencies is required for each circuit. For the purpose of simplifying operation and for economy of frequency space, each pair of frequencies is considered as being associated with a particular shore station rather than any particular ship. In order to give service simultaneously from both the American and European shore stations, therefore, separate pairs of frequencies are required for each shore station. At the present time there are really only two such stations offering a general North Atlantic service whose operations must be coördinated; namely, that of the British General

Post Office (transmitting and receiving stations at Rugby and Baldock, respectively), and that of the American Telephone and Telegraph Company. The shore stations always work on their respective frequencies in each mobile service frequency band and the boats change, depending on whether they wish to work London or New York.

For any given distance range there is a definite pair of frequencies for working with New York and another definite pair of frequencies for working with London.

The requirement of being able to work as continuously as possible across the Atlantic was a determining factor in deciding upon use at each station of four pairs of transmitting and receiving frequencies—one pair for each of the various distance ranges. The utility of the different frequency bands is given below.

TABLE I

Approximate Frequency in Megacycles per Second		Approximate Distance Range in Nautical Miles	
		Day	Night
Summer	4	0– 250	0– 700
	8	250– 700	700–2500
	13	700–1600	2500–3500
	17	1600–3500	—
Winter	4	0– 300	0–2500
	8	300– 800	2500–3500
	13	800–2000	—
	17	2000–3500	—

The actual frequencies which are now used are given in the table below.

TABLE II
FREQUENCIES USED FOR SHIP-SHORE TELEPHONY

American Telephone and Telegraph Co.—Transmitting Station, Ocean Gate, N. J.	Ships Transmitting to		British General Post Office—Transmitting Station, Rugby, Eng.
	Forked River, N. J.	Baldock, Eng.	
17120 kc.	17640 kc.	16440 kc.	17080 kc.
12840	13210	12380	12780
8560	8830	8860	8680
4752.5	4177.5	4430	4975

To change from one transmitting frequency to another requires changing coils, readjusting tuning, and connecting the transmitter to the proper antenna. Experience has shown that at Ocean Gate this can be done in as little as three or four minutes by coöperation of several station attendants, but that five to seven minutes are preferable in order to minimize chances of error in adjustment.

The use of two receivers at the shore station, one of which has two input circuits, including beating oscillators, each circuit tuned to a different frequency and connected to the proper antenna, makes it possible to operate at three of the four frequencies without any changes in receiver adjustment. The flexibility of this shore receiving station is further enhanced by use of an antenna transmission line switching panel whereby any receiver can be connected quickly to any antenna.

With only one shore station the obvious plan of establishing contact is for each of the boats to have its transmitter prepared to operate on the frequency suitable for its particular distance from the shore station and to monitor continuously the frequency the shore station would use for that distance. The shore station would monitor all of the four frequencies (one for each of four zones). This would permit the shore station to call a ship at any time and receive an immediate answer and would permit a ship to call the shore and either receive an immediate answer or to be answered as soon as the shore station could change to the required transmitting frequency. To use this method with two shore stations makes operation less straightforward. In the first place, each ship would have to be equipped with two receivers, one for monitoring each of the two shore stations. Furthermore, unless the ship were equipped with two transmitting sets, it could not be prepared to answer immediately, since it would not be certain as to which shore station might call and, therefore, would not know which of two transmitting frequencies it would be required to transmit on. The additional ship equipment, the possible delay in the ship's changing frequency, and the possibility of both shore stations wanting to work the same ship at the same time, resulted in the working out of a zoning plan of operation which is now being used and which is essentially as follows:

1. The North Atlantic is divided along the 37° 30' meridian into two zones—the American and the European.
2. London works with ships in the European zone, during the time New York works with ships in the American zone.
3. Similarly, London works with ships in the American zone, during the time New York works with ships in the European zone.
4. Because the density of traffic is greater in the zone adjacent to the shore station, the length of time that London and New York work with ships in their respective home zones is set at 3 hours with intervening 2-hour periods to work with ships in their foreign zones. To keep this ratio but reduce the period of the cycle was not thought practical because of delays in establishing contacts—either due to time required for changing frequencies or to poor transmission.

The reduction of this to a definite operating scheme can be best discussed in conjunction with Fig. 13. This shows a chart for Octobr 7, 1931, such as is used by the technical operators at the New York terminal. The abscissas indicate the space between New York and London, marked off both in degrees longitude and in nautical miles from Ambrose Channel Lightship. Time of day is plotted along the ordinate. The straight slanting lines represent the positions of the ships concerned at various times of the day. The slanting line marked "ship's noon" facilitates checking of the estimated position with that reported by the ship. The rectangular enclosures show the periods during which the New York terminal works with ships in either zone. These enclosures are divided by dotted lines, each portion containing a number

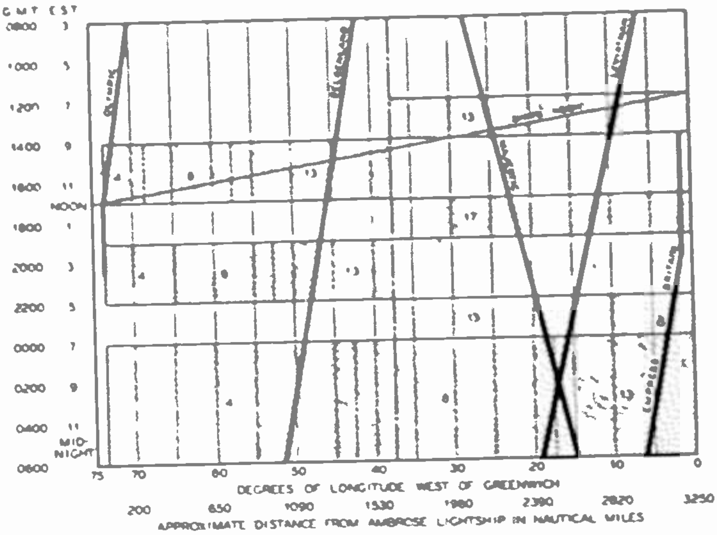

Fig. 13—Approximate ship positions for October 7, 1931.

which designates in megacycles the band in which the frequencies lie on which the ship and the shore station will make contact.

Up to 7:00 A.M. New York time, there is little demand for traffic with New York so no regular schedules are arranged with the ship. This period is London's forenoon and London is free to work any or all ships regardless of their geographical position. Between 7:00 A.M. and 9:00 A.M., New York works with ships whose positions are east of the 37° 30′ meridian. Similarly and simultaneously, boats west of the 37° 30′ meridian will work with London on frequencies designated by a somewhat similar chart. As indicated on this particular chart, from 7:00 A.M. to 9:00 A.M., New York works with the Steamships Leviathan and Majestic on 13 megacycles, while London works with the Olympic and Belgenland.

Between 9:00 A.M. and 12:00 noon, New York time, New York and London work ships in their respective adjacent zones; namely, London works with the Leviathan, the Empress of Britain, and the

Majestic, while New York works with the Olympic on 4 megacycles, and with the Belgenland on 13 megacycles.

Between 12:00 noon and 1:00 P.M., the shore stations work the further zones again and so on until 7:00 P.M. (midnight in London), after which there is little traffic demand in London and New York works with any ship regardless of its geographical position.

Recently the Empress of Britain has opened service with the Canadian Marconi Company stations near Montreal and utilizes the two one-hour periods, 11:00 A.M. to 12:00 M., and 4:00 to 5:00 P.M., New York time, regardless of the ship's position.

Knowing the geographical position of the ships, the operators on both ship and shore know exactly the periods in which they are expected to make contact, and on what frequency. During this period the ship ignores the other shore station entirely unless special arrangements have been made for exceptions to the plan.

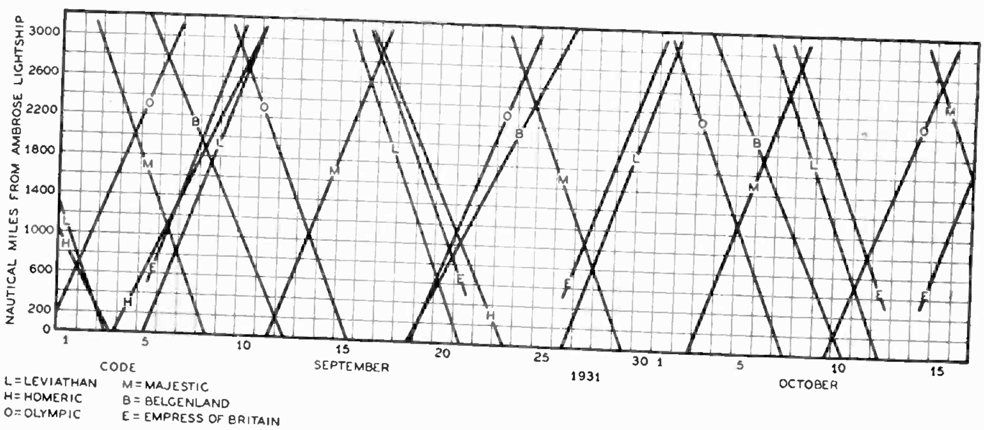

Fig. 14—Sailing schedules of ships with which ship-shore service is given.

The distribution of ships varies, of course, from day to day, as is seen from Fig. 14. This has distance along the vertical scale and days along the horizontal. The straight lines indicate the positions of the various ships from day to day. A line slanting downward from left to right indicates a ship coming from Europe to New York and a line slanting upward left to right indicates a ship bound for Europe from New York.

IV. Operating Results

Some idea of the effectiveness of transmission on the various frequencies and the general reliability of the ship-shore service can be derived from Fig. 15. There is one chart for each of the four frequency bands and a summary of all frequencies at the bottom. Each chart shows the percentage of the total observations when excellent, good, fair, uncommercial, and hopeless circuits were obtained for the various distances. The results shown were obtained on transmission from Ocean Gate, N. J., to all the ships during daylight hours for the period

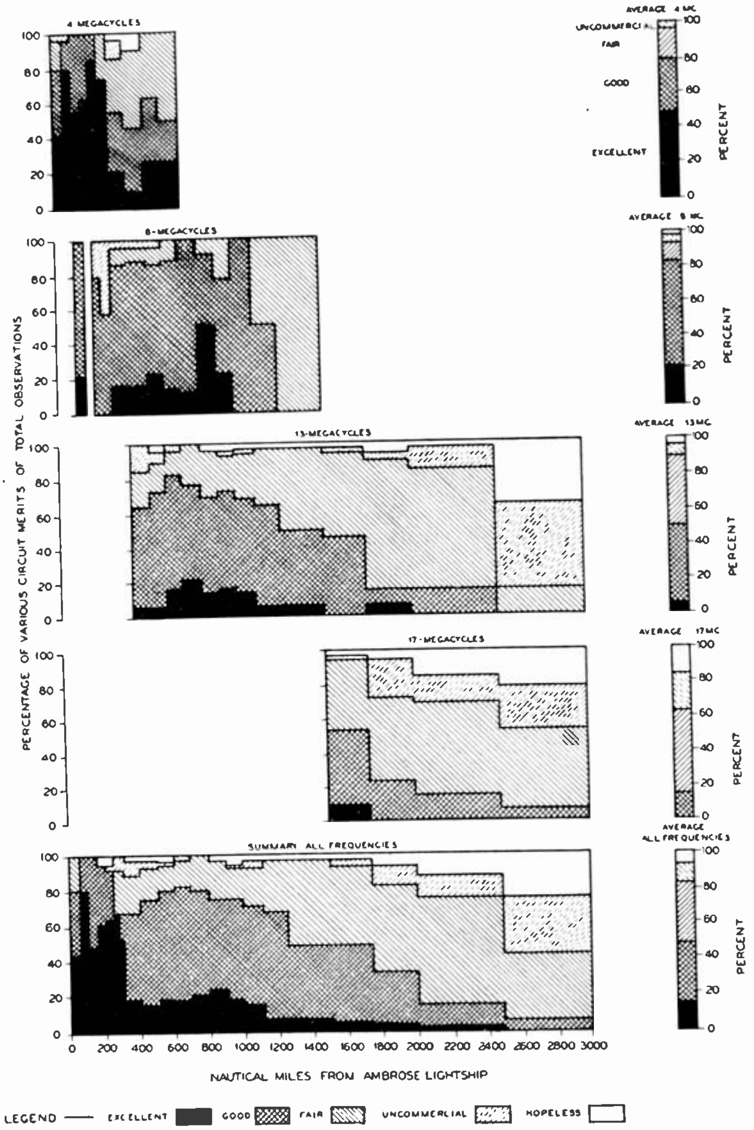

Fig. 15—Percentage of various circuit merits for various distances. Daytime transmission from Ocean Gate to all ships, January–June, 1931.

January–June, 1931, inclusive, the merit of the circuit being estimated by the operators on the various ships. The chart at the top is for transmission on a frequency of approximately 4 megacycles and indicates a high degree of reliability. The following three charts are for transmission on 8 megacycles, 13 megacycles, and 17 megacycles, respectively.

The summary chart at the bottom indicates that the reliability decreases with increasing distance but on the whole about 85 per cent of the contacts have resulted in commercial circuits.

Fig. 16 summarizes the performance of the circuit from ship to

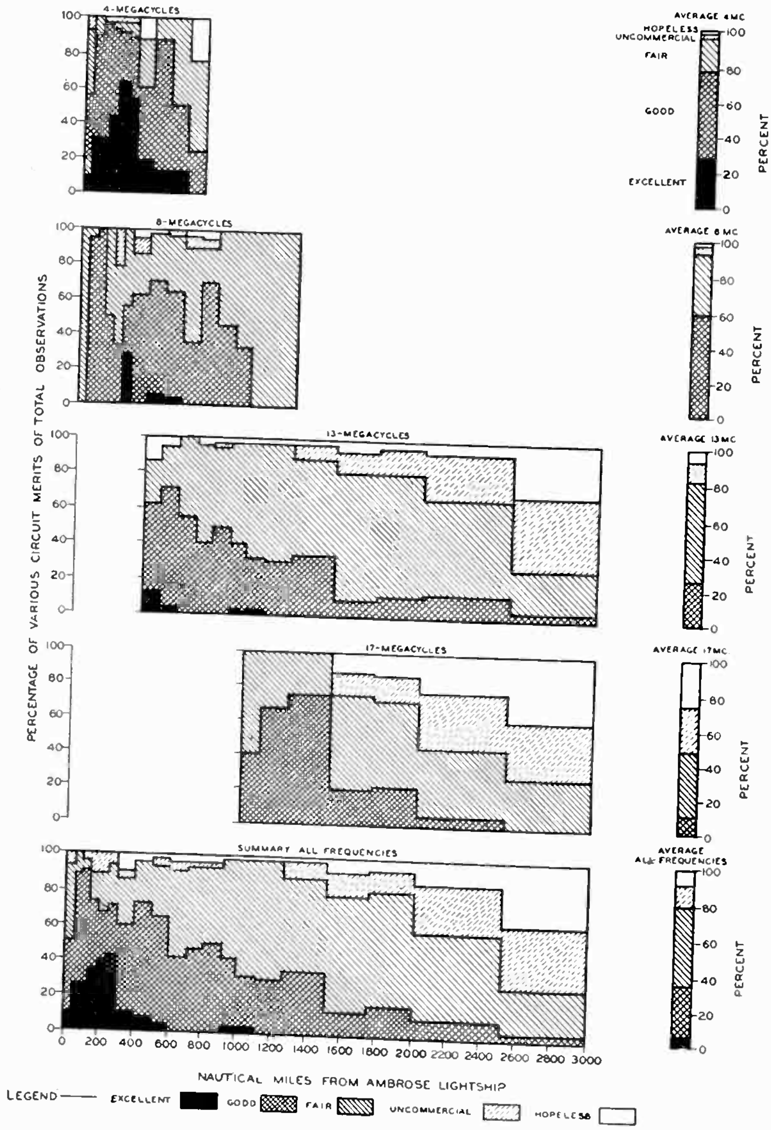

Fig. 16—Percentage of various circuit merits for various distances. Daytime transmission from all ships. Observations at Forked River, New Jersey, January-June, 1931.

shore at various distances in terms of circuit merits. These results are for transmission from all ships to the Forked River receiving station. The results are similar to those obtained for transmission from the shore, although generally poorer.

The distribution of calls with distance from New York is shown in Fig. 17. It is of interest to note that while traffic is handled over the entire distance, the greatest density of completed calls occurs at dis-

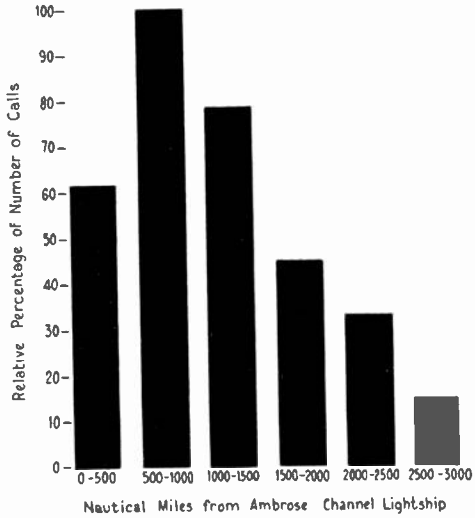

Fig. 17—Distribution of calls with distance, May, 1930–June, 1931.

tances between 500 and 1000 miles from New York, and that nearly 75 per cent of the calls occur within 1500 miles of New York. One factor which may possibly affect this distribution is the reliability of

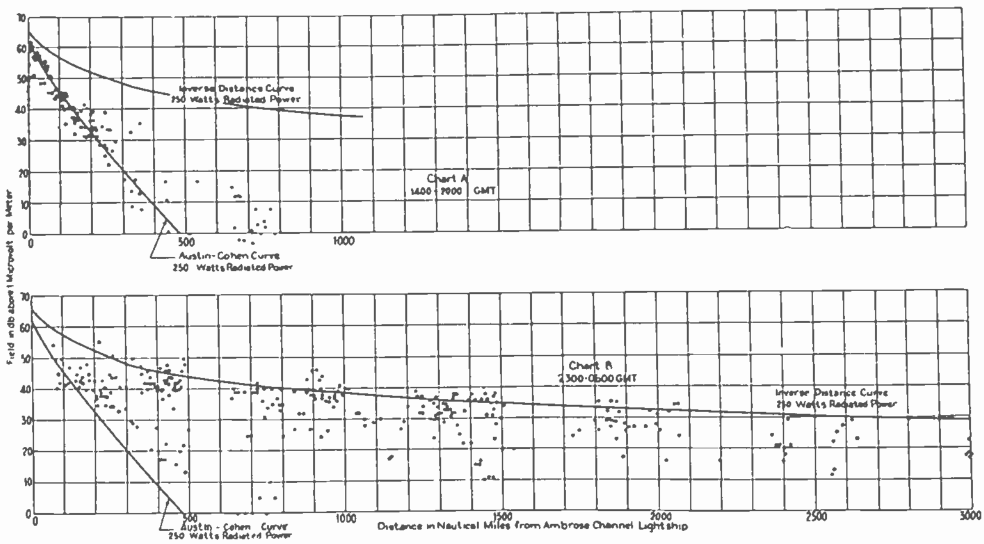

Fig. 18—Variation of radio field strengths with distance. Frequency 4 mc. November–February, 1929–1931. Transmissions from ships in North Atlantic steamship lanes to Forked River, New Jersey.

the circuits at different distances as shown in Figs. 15 and 16. The distributions on both inbound and outbound trips are essentially the same.

Radio field strength measurements have been made at Forked River on most of the daylight transmissions from the various ships. Fig. 18 shows a plot of some of the 4-megacycle fields as a function of distance. Chart A shows the variation of the fields for the hours 9:00 A.M. to 3:00 P.M., E.S.T., inclusive, in winter, (1400–2000 G.M.T.) and Chart B shows the same for the nighttime hours, 6:00 P.M. to 1:00 A.M. (2300–0600 G.M.T.). Within the accuracy of the data, the minimum daytime fields appear to be approximated reasonably well by the curve representing the Austin-Cohen values for transmission over sea water and assuming 250 watts radiated power. Correspond-

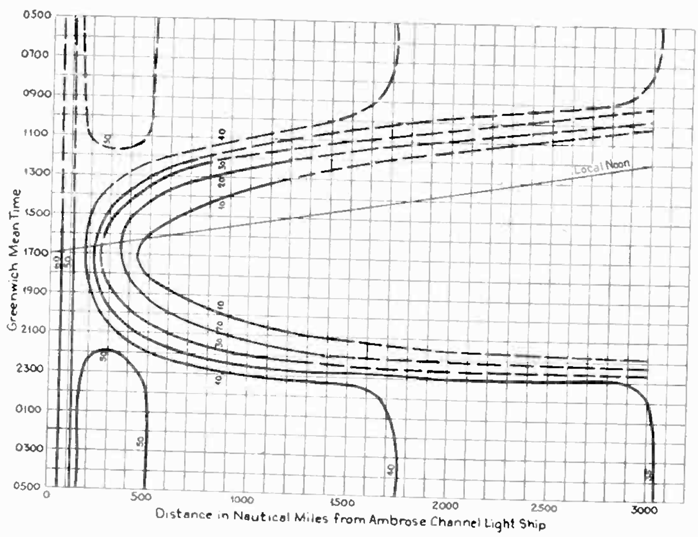

Fig. 19—Approximate variation of radio field strengths with distance and time of day. Contour lines indicate maximum expected field strengths in decibels above 1 microvolt per meter. Frequency 4 mc. Winter. Corrected to 1-kw radiated power.

ingly, the maximum night values are approximated by the inverse-distance law, also with 250 watts radiated power. The data at distances less than 50 miles from Ambrose lightship are unreliable as they involve some overland transmission.

From similar curves for the various hours of the day, the contour diagram shown in Fig. 19 was obtained. The contours represent the maximum values which may be expected, as the actual values may fluctuate from these maximum values to below the limit of measurement, depending upon the condition of the transmitting medium at the particular moment. This is shown in Fig. 18. Fig. 19, together with Figs. 20, 21, and 22, which show contour diagrams for other frequencies, gives some indication of the relative transmission on these frequencies for various distances and at various times of day. It is of interest to note that in the wintertime there appears to be no advantage from the standpoint of maximum values of measured signal fields in using 17 megacycles, rather than 13 megacycles. There may be occasions, however, when maximum fields are realized on 17 megacycles, when they

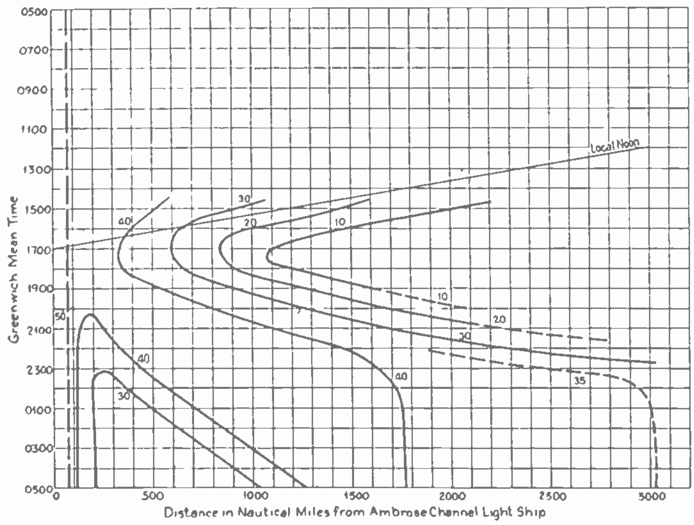

Fig. 20—Approximate variation of radio field strengths with distance and time of day. Contour lines indicate maximum expected field strengths in decibels above 1 microvolt per meter. Frequency 8 mc. Winter. Corrected to 1-kw radiated power.

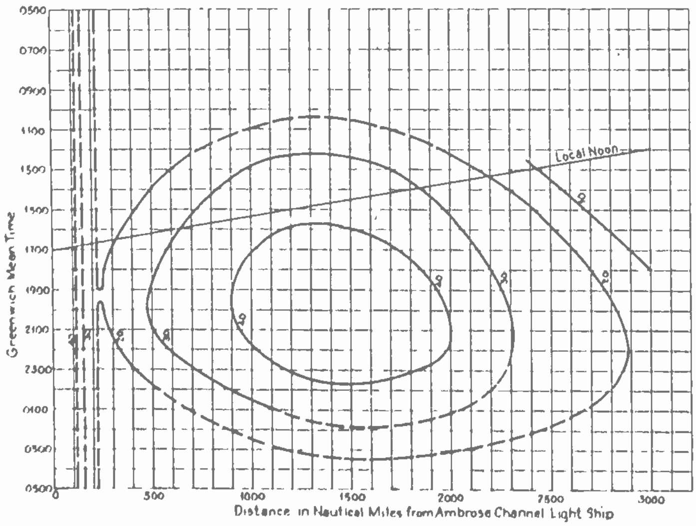

Fig. 21—Approximate variation of radio field strengths with distance and time of day. Contour lines indicate maximum expected field strengths in decibels above 1 microvolt per meter. Frequency 13 mc. Winter. Corrected to 1-kw radiated power.

are not realized on 13 megacycles, and of course, the lower noise obtaining on 17 megacycles has not been taken into account.

Although the contour diagrams give a fair representation of the data as obtained, they should be regarded as subject to considerable reservations. First of all, the data are not as complete as desirable and it is to be remembered that the measurements have been made inci-

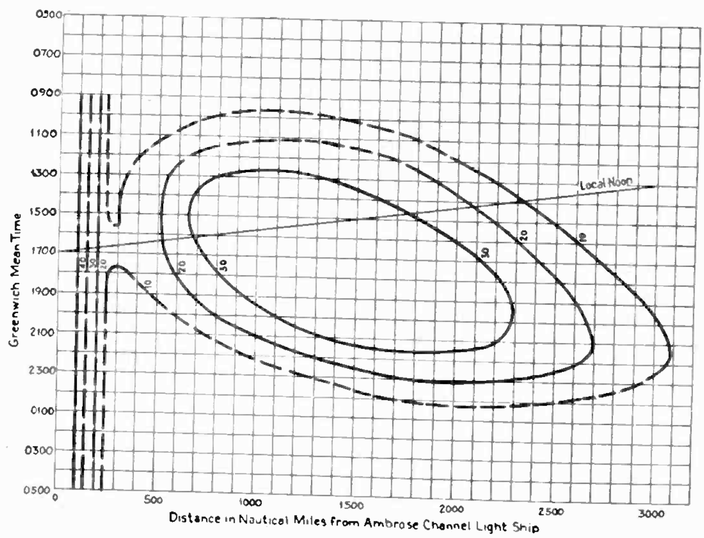

Fig. 22—Approximate variation of radio field strengths with distance and time of day. Contour lines indicate maximum expected field strengths in decibels above 1 microvolt per meter. Frequency 17-mc. Winter. Corrected to 1-kw radiated power.

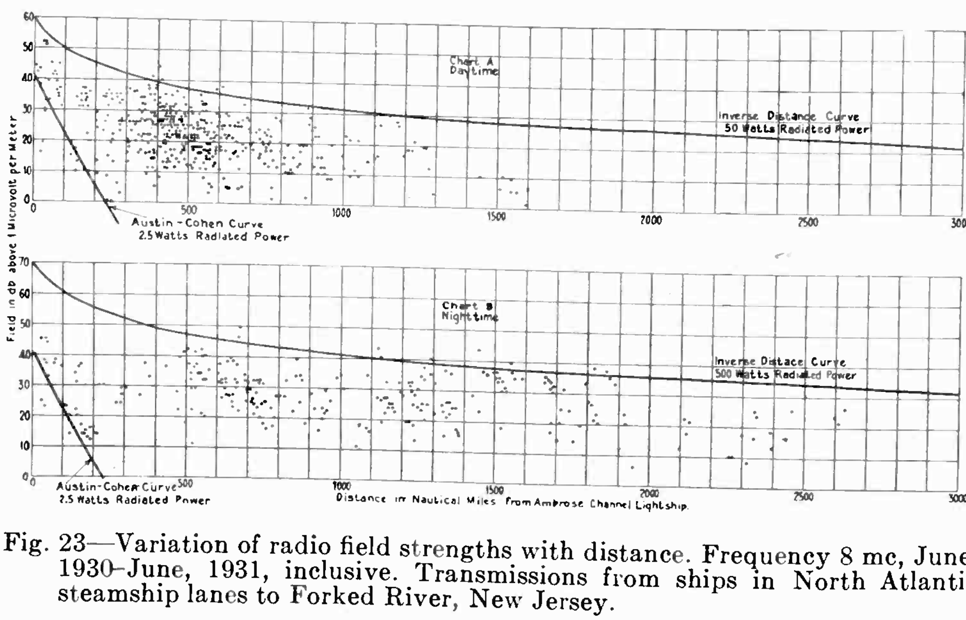

Fig. 23—Variation of radio field strengths with distance. Frequency 8 mc, June, 1930–June, 1931, inclusive. Transmissions from ships in North Atlantic steamship lanes to Forked River, New Jersey.

dental to the operation of the service and not as part of a laboratory experiment. There is evidence, furthermore, to show that the power outputs of some of the ship transmitters are subject to considerable fluctuation. Then there must be considered the possibility of errors in measurements and in the analysis of the data which are very hard to eliminate entirely. After taking these matters into consideration there still remains the possibility that the directional characteristics of the

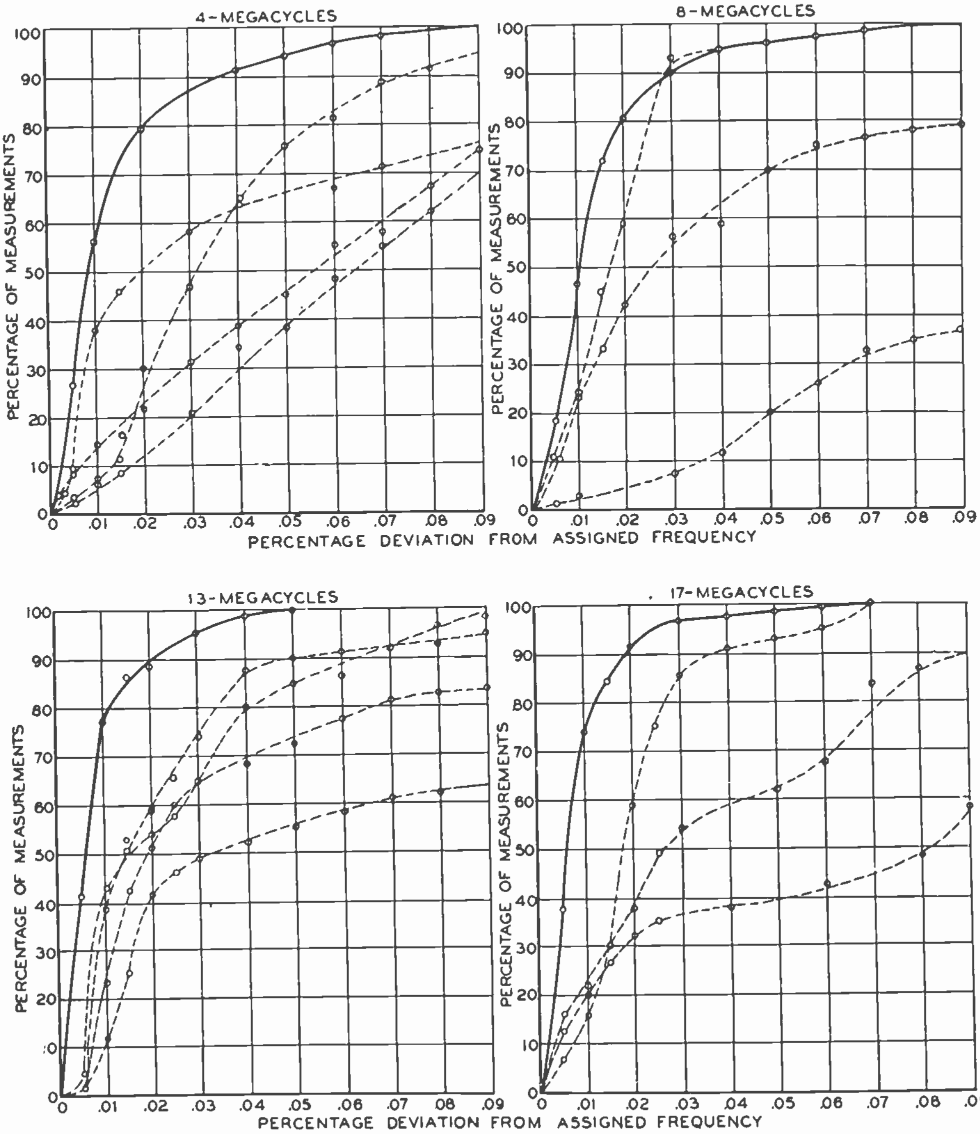

Fig. 24—Variation of transmitting frequency from the assigned. Percentage of measurements with deviations less than the abscissa value. Although curves indicate results for the period April, 1930–July, 1931, there was considerable improvement toward the latter part of the period. Solid curve—shore transmitting station. Dotted curve—ships.

transmitting and receiving antennas in the vertical plane may have affected the contour diagrams so as to make them applicable only in particular cases. Fig. 23 illustrates the point in question. This figure shows the daytime and nighttime fields for 8 megacycles transmission plotted as a function of distance. It will be noted that the maximum values for daylight transmission indicate a power radiated which is about 10 db less than that indicated by the maximum night values. If it be assumed that the minimum daytime and nighttime fields (ground wave) be approximated by the Austin-Cohen formula, as appears to be the case for 4-megacycle transmission, the effective radiated power for this transmission is even less. One possible explanation is that the effective daytime sky wave and the ground wave for both day and night result from relatively low angle radiation (and reception), whereas the effective nighttime sky wave results from higher angle radiation (and reception) and from a more effective position of the antenna vertical directional characteristic.[8] The frequency at which this characteristic becomes apparent seems to be between 4 megacycles and 8 megacycles.

Fig. 24 shows the variations in frequency of the various transmissions involved in the ship-shore service for the period April, 1930 to June, 1931. There is one set of curves for each of the four frequency bands; namely, approximately 4 megacycles, 8 megacycles, 13 megacycles, and 17 megacycles, and each set shows the frequency deviations for the shore station at Deal and Ocean Gate and for four of the ships which have been in operation the greater portion of this period. For the shore station, practically 100 per cent of the frequency measurements lie within the 0.05 per cent allowable deviation. For the ship stations the results are not as good, however, and such deviations constitute one of the difficulties in facilitating prompt contact between the ship and shore. A gradual improvement has been made in frequency stability aboard ship, so that the results for the last few months of the above period have been considerably better than indicated. However, because of sacrifices in facilities for checking frequencies resulting from compactness of equipment, less personnel, and greater number of frequencies which have to be provided for, the results of frequency stability on the ships have not been as satisfactory as on shore.

V. Conclusion

The major physical problems involved in the establishment of public telephone service from the land line network to large transatlantic liners have now been reasonably well solved. Experience over the past two years has shown it to be possible to maintain a fairly reliable serv-

[8] *See also,* R. K. Potter and H. T. Friis, "Some effects of topography and ground on short-wave reception," to be published in a forthcoming issue of the Proc. I.R.E.

ice over distances up to about halfway across the Atlantic and to give some measure of service all the way across. This means that transatlantic vessels can obtain fairly reliable telephone service to either the European or the North American continent during the entire transatlantic passage. The operating plan which has been developed enables the shore stations on either side of the Atlantic to establish scheduled contacts at frequent periods during the day with all ships.