GREAT LAKES RADIOTELEPHONE SERVICE

By
H. B. Martin

Engineering Department, Radiomarine Corporation of America

Summary—The radiotelephone communication systems now in use on the Great Lakes are similar in many respects to United States Coastal and Harbor services. Radiotelephone on the Great Lakes is used primarily for dispatching cargo vessels and for communication with pleasure craft.

The Federal Communication Commission does not require radio equipment on Great Lakes vessels except those in the passenger-ship classification.

During the last three navigation seasons, the use of radiotelephone communication for business, pleasure, and safety purposes has shown considerable growth.

PRESENT-DAY radiotelephone communication on Lakes Erie, Huron, Michigan, Ontario, and Superior presents many problems which differ from established practices on the Atlantic and Pacific coasts of the United States.

Radiotelephone communication with vessels using coastal ports may be divided into two classes. In one class fall the trans-oceanic passenger liners which employ radiotelephone as an added service in conjunction with the regular radiotelegraph service carried for safety-of-life-at-sea and for public correspondence. Ships in this category utilize relatively expensive and complicated equipment which must of necessity be operated by skilled radio personnel. Multi-channel transmitters in the order of 400 and 600 watts output are commonly employed to enable reliable communication with high power coastal telephone stations over distances of several thousand miles.

The other class of vessels using radiotelephone on salt water and tidal rivers includes cargo vessels, yachts, tugboats, fishing vessels, and small craft. These vessels carry radiotelephone equipment designed to communicate over relatively short distances such as within harbors and along the coasts. A number of harbor-telephone stations have been established along the United States coastlines for this type of service. At the present time nine stations for harbor service are in operation and others are contemplated. Since communication is never intended over large distances, the allocated frequencies are in the 2100 to 2600 kilocycle band.

The Canadian-American agreement of 1933 allocated certain frequencies between 2100 and 2600 kilocycles for use on inland waterways, including the Great Lakes and the Gulf of St. Lawrence Waterway. Due to the geographical separation and the distance ranges of the frequencies involved, it is possible to duplicate frequency assignments. The following tabulation shows ship transmitting and receiving frequencies as contemplated for use on the Great Lakes and the Gulf of St. Lawrence:

Location of Ship	*Ship Frequency*	
	Transmitting	*Receiving*
On Lakes Superior and Erie	2158	2550
On Lakes Michigan and Ontario	2118	2514
On Lake Huron	2182	2582
On St. Lawrence Waterway	2190	2598

Special temporary rules, governing radiotelephone operation on the Great Lakes for the 1939 navigation season issued by the Federal Communications Commission effective March 31, 1939, change the above assignments. The frequency 2182 kc may be used by all Great Lakes shore and ship telephone stations for calling and for safety purposes. After communication has been established between the ship and shore stations, both stations will change to the traffic frequencies, either 2118 and 2514 kc or 2158 and 2550. Ships are not authorized to transmit on the traffic or working frequencies unless directed to do so by the shore station contacted. Such a system will prevent a ship from interfering with a conversation already in progress. In the case of ship-to-ship communication, both ships would change to 2738 kc after first having established communication on 2182 kc.

The U. S. Coast Guard will operate all of its approximately fifty radio stations on the five lakes to conform to this plan. These stations are being equipped to operate on 2182 kc so that ships requiring assistance or emergency information may call the nearest Coast Guard station directly and obtain assistance or information.

The rules also provide a special marine broadcast frequency of 2572 kc for periodical weather information.

New frequencies 4422.5 and 4282.5 ks for ship-shore communication are authorized for daytime use only. In addition, a new day-only intership frequency of 5532.5 kc has been allocated.

General Requirements for Receivers

Since frequencies adjacent to those used on the Great Lakes are used in other areas, the selectivity of ship receivers should be such that signals having a carrier frequency 8 kilocycles removed from the desired signal will be highly attenuated.

Equipment designed for the reception of voice only from the harbor stations must be capable of selectivity equal to or better than standard broadcast practice. Selectivity, such as required, is attained in practice only by the use of well-designed receivers of the superheterodyne type where high adjacent channel attenuation and optimum gain are possible with a minimum number of tuned circuits. It is well known that for random received noises, such as atmospherics, the voltage present in the receiver output, as a result of these noises, will vary as the square root of the effective band width of the receiver. The receiver radio-frequency oscillator must, of necessity, equal the stability of the shore station transmitters which are required by regulation to maintain frequency within ± 0.02 per cent. For example, a shore station operating on 2500 kc would have a tolerance of only ± 500 cycles. If the receiver intermediate amplifier (wherein the receiver derives most of its selectivity) is assumed to have a response essentially flat for transmitter side bands up to 2700 cycles, in order to give good voice reception and limit received noise, the receiver oscillator could be off frequency only a small amount without noticeable side-band attenuation. In order to maintain frequency stability as required, the receiver r-f oscillator must be quartz-crystal controlled.

To allow communication with weak signals the shipboard receivers must be capable of reasonable headphone or loudspeaker signals with inputs of 5 microvolts absolute or less. Electrical machinery and static will, in many cases, prevent usable sensitivities of this order since, assuming a receiving antenna of 5 meters effective height, it is more than likely that noise in excess of a signal of 1 microvolt per meter would be received.

Fading is usually present beyond the normal primary service area of the shore station which necessitates the use of automatic volume control in order to reduce the effects of fading. Automatic volume control is also desirable to prevent overloading and distortion when strong signals are received. It is well-known that delayed automatic volume control is desirable for weak signal reception in field strengths only a few microvolts above the noise level. The receiver "noise-equivalent", which is a figure-of-merit for modern receivers, must be low enough so that "carrier-hiss" is only a fraction of the audio output obtained when weak signals are received. The "noise-equivalent" effectively determines usable minimum signal reception since a signal which is present, but masked by noise is of no value for communication. Radio-frequency amplification ahead of the mixer or converter stage is always desirable so that receiver hiss may be reduced to values determined by "first-circuit" noise.

The audio output of marine telephone receivers must be sufficient to overcome room noise when the vessel is in rough weather. Audio fidelity should be purposely restricted to frequencies containing essentially all of the intelligence in a voice-modulated carrier.

Transmitter and Wave Propagation Considerations

The Federal Communications Commission licenses harbor telephone stations for an antenna power of 400 watts. Propagation conditions are variable depending on the frequency, power, transmitting site, antenna efficiency, time of day, and the season of the year. For frequencies in the order of 2500 kc it has been shown[2, 5] that attenuation is 6 to 12 db per mile of overland transmission. The attenuation is greatest adjacent to the transmitting site in the case of a station located inland. When 400 watts antenna power at 2500 kc and an antenna efficiency of 50 per cent is assumed, the radiated power would be reduced to approximately 100 watts at the shore if the station is one mile inland. This figure is based on the assumption that field strength is attenuated 6 db for the first mile of overland transmission. For this reason, in order to realize ground-wave field strengths as large as possible with relatively low power, land stations for communication with ships are always located as close to the shore as practicable.

The conditions for ground-wave propagation over sea water are considerably better[3, 4, 6]. The attenuation over sea water is less than 0.1 db per mile so that for 60 miles the signal would be reduced not more than 6 db below the inverse distance field, resulting in a field strength of approximately 300 microvolts. Attenuation over fresh water is somewhat more than over salt water so that the exclusively ground-wave or primary-service area of the average 2000 kc, 400-watt station may be only 25 to 50 miles over fresh water and intervening land. During daylight hours the reflected sky wave does not become appreciable under 50 miles. Since atmospherics are at a minimum near noontime, it is usually possible to communicate farther, by means of the ground wave, during the day than at night. For example, during August, 1938, tests were conducted between Harbor Station WAY (2514 kc), Lake Bluff, Illinois and low-power telephone equipment on boats up to 70 miles north of Lake Bluff along the western shore line of Lake Michigan. It was found that commercial signals were obtainable on both ends of the radio link at distances of 50 to 60 miles during the middle-daylight hours, but from late afternoon throughout the night, the increase in atmospherics limited communication to about 30 miles. Transmitters delivering 5,[8] 15,[7] and 50 watts were used for transmissions to WAY. During October, November, and until the close of Great Lakes navigation, it was generally possible to carry on commercial telephone calls with WAY up to distances of 450 miles at night.

Great Lakes Telephone Shore Stations

The Canadian Government has, for several navigation seasons been carrying on limited tests with Canadian boats equipped with Marconi radiotelephone apparatus. Following is a tabulation of Canadian shore stations:

VBA	Port Arthur, Ontario	(Northwestern Lake Superior)
VBB	Sault St. Marie, Ontario	(Junction Lakes Superior and Huron)
VBC	Midland, Ontario	(Georgian Bay, Lake Huron)
VBE	Sarnia, Ontario	(Lower Lake Huron)
VBF	Port Burwell, Ontario	(Lake Erie)
VBG	Toronto, Ontario	(Western Lake Ontario)
VBH	Kingston, Ontario	(Eastern Lake Ontario)

These stations were established primarily for radiotelegraph communications and the telephone apparatus has been located adjacent to the radiotelegraph equipment and is operated by the same personnel. VBB and VBG during the 1938 season transmitted on either 2550 or 1630 kc and maintained a watch on 1630 kc for 50 minutes then changed to the 2158 to 2550 channel for the remaining 10 minutes of each hour. The five other stations used only 1630 kc for both transmitting and receiving. It is expected that the Canadian radiotelephone stations will conform to the new plan. The Canadian ship stations use antenna power of approximately 25 watts and the shore stations of approximately 100 watts. Telephone communication to Canadian stations is on a "message" basis, it being necessary for the shore operator to write down the telephone message from the ship, convey it to its destination by land-line telephone or telegraph, receive the answer, if any, the same way, and read the message to the ship. Such a system is considerably slower in operation than the procedure employed by the United States stations now in operation where the ship is connected directly to the subscriber called just as in long-distance, land-line practice.

There are at present four United States Harbor or Coastal-Harbor telephone stations for Great Lakes service as follows:

WMI	Lorain, Ohio	500 watts	(near Cleveland)
WAY	Lake Bluff, Ill.	400 "	(near Chicago)
WAS	Duluth, Minnesota	400 "	
WAD	Port Washington, Wisc.	400 "	

It is estimated that 95 per cent of all Great Lakes cargo vessels are dispatched and directed from the Cleveland offices of the various shipping companies. Since reliable communication under adverse conditions is a matter of somewhat less than 100 miles in the vicinity of 2000 kc frequencies, additional frequencies normally allocated to ocean communication were assigned to WMI making that station a "Coastal-Harbor" service—the only one of its kind to date on the Great Lakes. The frequencies in use at WMI are as follows:

	For transmission	*For reception*
"Channel 30"	2550 kc	2158 kc
"Channel 20"	6470 kc	6660 kc
"Channel 10"	8585 kc	8820 kc

Channel 30 is used for all short distance communication in the western part of Lake Erie during the daytime and at night for any location in the lakes during low-static conditions, which normally occur only during early spring and late autumn.

Channel 20 is normally good for communication to any point in the lakes at night except for the gap between the ground wave and the beginning of the sky-wave reflection. The latter begins to be serviceable at about 100 miles from Lorain, Ohio whereas the ground wave is attenuated to non-commercial values only a few miles from the transmitting site.

Channel 10 is necessarily an exclusively daylight channel so far as Great Lakes communication is concerned since the minimum night time range of 8 to 9-megacycle transmission is about 1500 miles which is greater than the distance from Cleveland to any point on the Great Lakes. The minimum daylight range of this frequency is approximately 300 miles so that ships from lower Lake Huron to Duluth may normally use Channel 10 for communication with WMI during midday.

Station WAY is located at Lake Bluff, Illinois, and serves the lower part of Lake Michigan with Harbor Telephone service. WAY operates on 2514 kc with 400 watts power. Ships communicating with this station normally transmit on 2118 kc although the station is equipped to receive calls on any telephone frequency used on the Great Lakes.

Station WAS at Duluth, Minnesota operates on 2550 kc and is also rated at 400 watts power. It is expected that this station will improve communication facilities in the western part of Lake Superior inasmuch as the ore carriers, in order to receive docking and loading information, have previously depended on securing such orders from Cleveland via WMI. When it was necessary to converse with company agents in Duluth, or other harbors near the ore fields, a long radio link to Lorain, Ohio plus a long land-line connection was required.

Station WAD at Port Washington, Wisconsin operates on either 2550 kc or 2514 kc, the latter frequency being shared with station WAY. Port Washington is 70 miles north of Lake Bluff, Illinois.

Ship Equipment

Ship equipment, operated by holders of "Third Class Telephone" licenses, must of necessity, due to government radio regulations and from a practical standpoint, be comparatively low power, simple to operate, and incapable of causing interference to services on other frequencies. Ship telephone transmitters (except the ocean-liner types) vary in power ratings up to 75 watts output. Normally the superior receiving conditions on shore and the additional power used by shore stations balances the generally unfavorable conditions for transmitting and receiving aboard ships.

The size and construction of the vessel usually limits the transmitting antenna so that it must be inductively loaded. This is true even on ore carriers whose length generally exceeds 500 feet. Ore boats are similar to tankers, the cargo holds being between the engine room and the pilot house. Any radio antenna must extend forward from the foremast in order to allow loading and unloading the forward holds without letting down or moving the antenna. The greatest length from the top of the mast to the pilot house or captain's office (two usual locations of the transmitting equipment) is not more than 60 feet. An antenna of this length loaded to 2000 kc has a total resistance of 5 to 10 ohms of which probably no more than 1 to 2 ohms are radiation resistance, the balance being distributed between dielectric losses, ohmic resistance, leakage, etc. If 75 watts transmitter output and an antenna efficiency of 20 per cent is assumed, the field strength at 50 miles, due to the ground wave only, would be approximately 200 microvolts per meter.[5] If the effective height of the ship receiving antenna is assumed to be 5 meters, the receiver r-f input would be 1000 microvolts. At 100 miles, and for the same assumed conditions, i.e. power, antenna efficiency, frequency, etc., the field strength would be approximately 80 microvolts per meter or 400 microvolts at the receiver input terminals.

In a great many cases, particularly on lakes, in harbors, and on inland waterways in general, the transmission path is along the coastline or over intervening land forming a large percentage of the propagation path. The attenuation of signals over fresh water is known to be greater than over salt water. In the case of predominant overland transmission, the attenuation would be such that at 50 miles, a 75-watt ship transmitter could be expected to produce a field strength of approximately 2 microvolts per meter. Obviously local ship interference caused by electrical machinery and static conditions may frequently be in excess of the received signal strength. Pertinent literature contains many statements relative to signal-to-noise ratios for telephone communication. While this is a debatable point, it is generally conceded that for the reception of news broadcasts and voice only, in cases where the listener has some special reason for wanting to listen and will tolerate annoyance, the signal must be 10 times stronger than the average noise level[1]. Measurements made during summer static conditions to indicate ratios of peak to average values show that during the day the ratio varies between 80 to 1 and 2 to 1, averaging a ratio of about 10 to 1. During the night, measurements showed the ratio to vary between 30 to 1 and 2 to 1, averaging 5 to 1. Apparently the night-time ratios of peak to average noise are more favorable for communication, since it is the peak crashes which obscure communication with weak signals.

It must be remembered, however, that average static levels at night may be 10 times the average day values so that in general and except in rare cases when there is little night static, the primary service range of a station is greater in the daytime than at night.

Actual observations made on the Great Lakes during November, 1938 and April, 1939 using transmitters of 75 watts power showed that daylight intership communication over water and intervening land on 2738 kc was practical up to 100 miles in the absence of static. Night-time intership communication was a variable factor. On occasion it was possible to carry on conversations up to 600 miles over lake water and intervening land. At other times difficulty was experienced in attaining a 50-mile range.

Calling Systems

The use of loudspeakers for standing-by or monitoring shore station and ship transmitting frequencies is objectionable for several reasons. First, several channels must be monitored simultaneously in order that calls may be received from any shore station operating on any one of several channels. For example, WMI uses three transmitting channels any one of which may be used to call the desired ship, depending on the location of the ship and the time of day. This would require a minimum of three receivers for monitoring WMI or similar stations and one for intership incoming calls. Calls on all channels whose propagation characteristics permit reception at the ship location would be heard by all ships. The continual blaring of a loudspeaker located in the pilot house would be a source of annoyance to such an extent that the speaker volume would be reduced, causing incoming calls destined for the ship in question to be missed. Also, loudspeaker monitoring of all channels simulates a "party-line" where all conversations are heard by all subscribers whether they intentionally listen or not.

The majority of Great Lakes ships using radiotelephone utilize loudspeaker monitoring arranged so that the speaker has a response characteristic peaked at 300 cycles. The shore station normally communicating with these ships calls individual vessels by transmitting a 300-cycle tone broken up into characters to simulate the ship's whistle signal. Each lake carrier ship has a code signal different from other ships and, therefore, quickly recognized by the ship's bridge personnel. Ships use the same method to call each other, the "longs" and "shorts" comprising the whistle signal of the boat called being made by manipulating a telephone dial. The digit "8" is usually dialed to transmit a "long" or dash and the digit "2" is dialed to transmit a "short" or dot. Hence, to call the "Wm. H Wolf," another boat would dial 8222 222 on the intership frequency. The first group is the *fleet signal* of the Gartland Steamship Company and the second group is the identifying or *name signal.*

Stations WMI, WAS and WAD use the whistle-signal system to call ships. Combined shore station calls and intership calls during certain hours of the day tend to make a bedlam of sounds in the pilot house speaker and as a result the loudspeaker volume may be reduced so as to be less of an annoyance. This would increase the attendant likelihood of missing calls.

Selective Signaling System

The two-tone audio-frequency, selective signaling system (when calling boats equipped with an automatic ringing device) has much to recommend it. This system has been developed particularly for marine telephone calling service and has been successfully used for a number of years by the Bell system harbor stations operating with harbor craft, yachts, fishing vessels, etc.

The selective signaling system has several distinct advantages over the loudspeaker method of attracting the attention of ship's personnel. The device is noiseless, faster and more accurate in its results. Except in exceptionally rare instances, a false alarm is practically impossible —the bell is rung *only* on the ship called and not on some potential 400 others. It is possible to put calls through when the shore station signals are only 2 db above the noise. Such a weak signal would be of little value for a commercial call, but would be usable in cases of distress. It is also possible to ring the bells on all ships at once in order to organize distress communication and establish control by shore stations or coast guard vessels.

The selective signaling device or automatic ringer, as it is sometimes called, consists fundamentally of a double filter network, two copper-oxide rectifiers, a polarized relay, and a stepping relay. The filters are fixed-tuned to 600 and 1500 cycles respectively. Each filter highly attenuates all frequencies except the one to which it is tuned. Separate copper-oxide rectifiers convert the filter outputs to direct current. The pulsating current is used to operate a polarized relay which is poled so that the reception of a 600-cycle audio tone in the radio receiver closes the relay in one direction where it stays until a 1500-cycle tone is received, which returns the relay armature to its opposite position. The reception of alternate 600- and 1500-cycle tones therefore causes the polarized relay armature to travel back and forth between fixed contacts. The function of the polarized relay is to charge and discharge a capacitor through the winding of a special stepping relay which must receive alternate impulses of capacitor charging and discharging current in order to operate the stepping and retaining mechanism. The stepping relay has a "code wheel" having movable pins which may be set in holes corresponding to any number desired so long as the sum of the digits in the number totals, for example, 23. The number of pins required depends on the number of digits. For example, a ship "telephone number" might be made up using three numbers such as 779, whose sum totals 23. The shore station impulsing telephone dial is specially constructed so that regardless of the number dialed the first digit of the next number will cause the opposite tone to be transmitted as A2 emission from the shore station. While it plays no part in the actual code, the digit "1" is always dialed as a prefix in order to reset the selector code wheel which might be resting on one of its pins and not at "zero," and in order to insure that all polarized relays are resting on either the 600- or 1500-cycle contacts. Actually, the *change* of tone from 600 to 1500 or vice versa, rather than the presence of either tone, causes the code wheel to advance.

Since the number of 3-digit codes whose sum equals 23 is limited, the use of a 5-digit code is recommended. For example, to call a certain ship, the shore station operator would dial 1 2 5 4 6 6. The prefix "1" moves the code wheel, but it returns to zero since no retaining pin is used in the number 1 position. Another ship might use the code 1 5 2 4 6 6, an arrangement which still totals 23 for the last five digits, but has the order of the 2 and 5 reversed. The code wheels of both ships, using the numbers as above, would step up to position 5 when the shore operator dialed "5," but only the second ship's code wheel would be retained at 5 and ready for the "2"; the code wheel on the first ship having fallen back to "zero" since no pin was in the 5 position. Using a five-digit code as above, over 2000 different ships could be dialed individually without the other ships being aware that a call or a conversation was in progress.

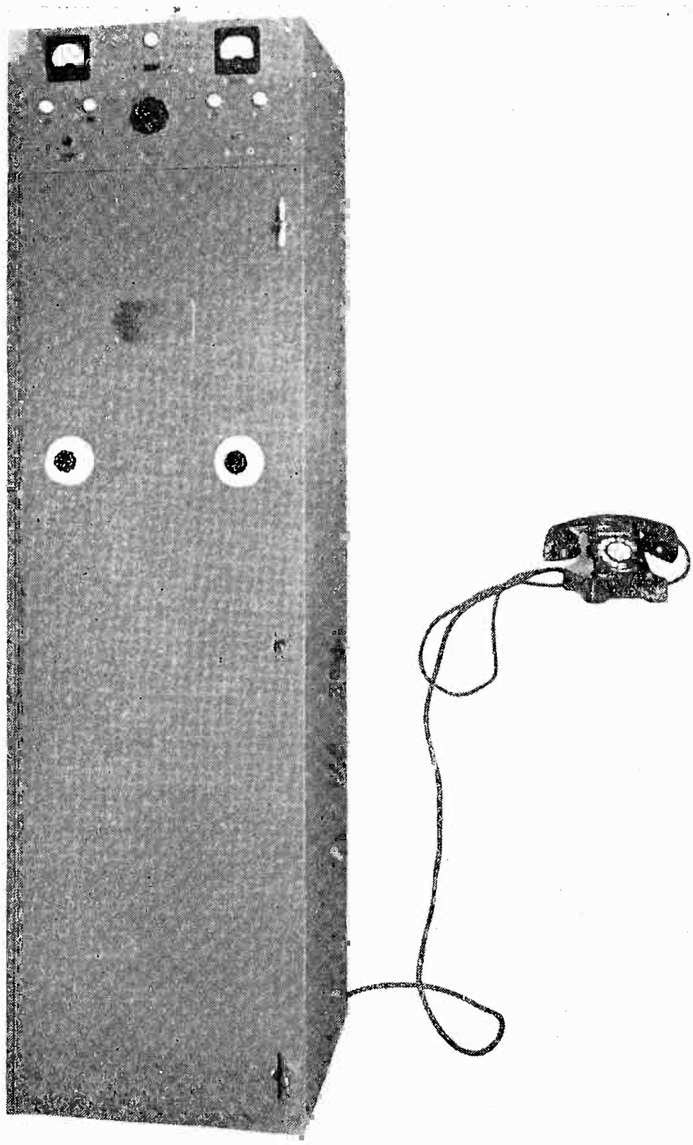

Fig. 1

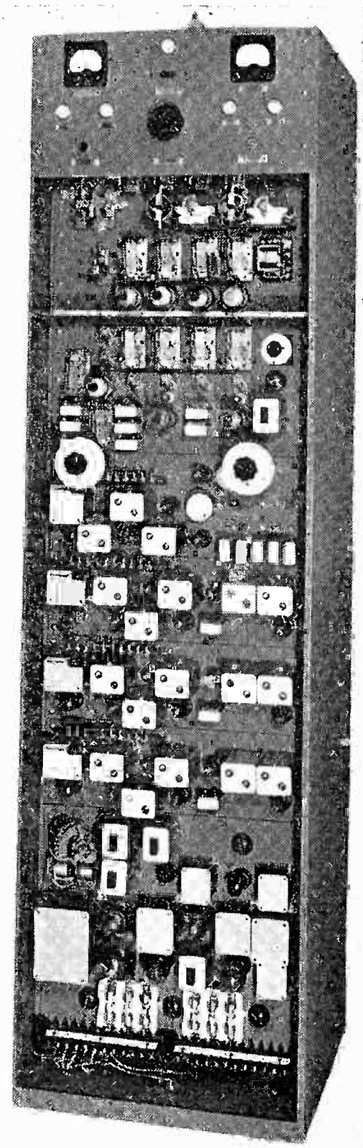

Fig. 2

Exterior and interior views of transmitting and receiving equipment used for four-channel operation.

Selective ringing can be applied to intership calling by somewhat complicating the ship transmitting equipment. Station WAY uses the selective ringing system for calling all ships so equipped.

Ship Radiotelephone Equipment

Figure 1 shows a view of ship equipment installed in 1938 and 1939 on several ore carriers operating on Lakes Erie, Huron, Michigan, and Superior. This equipment was especially designed for telephone communication on the Great Lakes.

The complete installation consists of:

- Transmitter and receiver cabinet
- Local hand set

Remote hand set
Loudspeaker and bell box
Motor generator and starter
Transmitting and receiving antennas

The main cabinet is 20″ wide, 20″ deep, and 72″ high. The front is hinged and swings open for access to the tubes, for servicing, initial tuning during installation, etc. A lock is provided on the door. Figure 2 shows the front opened for inspection. The lower section of the apparatus panel includes a terminal board and fuse block arranged for easy access. The lower panel has three adjustable controls for obtaining the correct receiving tube and transmitting tube heater voltages and the high-voltage d.c. used for transmitting. These adjustments are made during the installation and need no attention thereafter since none of the voltages are especially critical.

The transmitter audio-frequency tubes and associated parts are on the lower panel. A carbon-button microphone such as is used in land-line telephone service swings the grid of a Class A microphone amplifier which in turn supplies grid voltage for the driver stage. The modulators are arranged in a high-level Class B circuit and modulate the plate and screen circuits of the r-f power amplifier. The complete audio circuit is designed so that a normal voice level at the microphone will produce 60 watts of undistorted a-f power output. This is sufficient to modulate completely a d-c input of 120 watts in the r-f power-amplifier stage. High-level, plate-circuit modulation of a Class C, r-f amplifier, as used in this transmitter, is considered better practice than grid or suppressor circuit modulations, which although requiring less audio power, are subject to more distortion, are more difficult to adjust, are critical as to output loading, and definitely have more distortion at high percentages of modulation. The latter is particularly true of suppressor modulation. The overall power efficiency of high-level and low-level modulation is approximately the same since to get the same antenna power, the high-level system uses highly efficient Class C r-f amplifiers at the expense of having to develop high audio power whereas the low-level system conserves on audio power, but requires inefficient Class B operation of the r-f modulating amplifier.

The equipment shown in Figures 1 and 2 is for four-channel operation, but has the advantage that one of the channels may be tuned to any one of five transmitting and receiving frequencies. The middle section of the equipment panel contains four separate, six-tube superheterodyne receivers with crystal-controlled oscillators. Each receiver consists of a 6L7 r-f amplifier, a 6K8 mixer-oscillator, 2 6L7 i-f amplifiers, a 6R7 detector and audio amplifier, and a 25A6 audio power tube.

The combined output of the receivers is fed to the loudspeaker, selective ringer, or handsets as will be described later.

The four channels are known as 10, 20, 30, and 40. A tabulation follows:

Channel	*Ship Transmits On*	*Ship Receives On*
10	8820 kc	8585 kc
20	6660 kc	6470 kc
40 (intership)	2738 kc	2738 kc
30	2118 kc	2514 kc
30	2158 kc	2550 kc
30 (coast guard)	2182 kc	2182 kc
30 (coast guard)	2670 kc	2670 kc
30	—	—

Any one of the four channels may be selected by means of a telephone dial located on the local or remote handset mountings. Since Channel 30 is normally a short-distance or local channel, the ship is expected to set Channel 30 for the shore-station serving their location. For example, a ship while in Lake Michigan would set the Channel 30 knobs, which protrude through the front cover, for operation with WAY or WAD. When in Lake Superior or Lake Erie, the Channel 30 knobs would be set for operation with WMI, Lorain, Ohio or WAS, Duluth, Minnesota or Canadian stations at Sault St. Marie or Toronto, Ontario. If communication is desired with various Coast Guard stations, the Channel 30 controls would be set for 2182 kc. An additional channel-30 pair of frequencies may be added at any time whenever a station begins to use them.

Channel 40 is used exclusively for intership communication except that the Coast Guard station at White Fish Point, Lake Superior, is set up to use 2738 as well as 2670 kc for the exchange of weather information with ships. This was done because very few of the Lakes vessels are equipped to use the Coast Guard calling and emergency frequency of 2670 kc or the new 2182 kc safety frequency. It is believed that the use of 2738 kc by Coast Guard stations and cutters is only a temporary expedient, pending the installation of a 2182 kc channel on existing and new Lakes telephone equipment.

Channels 10 and 20 are used exclusively for long distance communication with station WMI.

The r-f portions of the transmitter consist of three separate oscillator tubes and four power amplifier tubes operated in parallel. The tubes used are of the "beam" type and require very little excitation for full output. One oscillator tube serves the intership and five channel 30 frequencies. The other two oscillators operate on 6660 and 8820 kc respectively. Special crystal-oscillator circuits are utilized so that crystal currents are relatively low and also in order that the Channel 10 and 20 crystals may be one-half the output frequency to insure reliability, low heating, negligible feedback, and consequently high frequency stability.

The power output circuits of Channels 30 and 40 are tuned by a high-efficiency adjustable-inductance circuit. The Channel 40 (intership) antenna circuit is fixed tuned to 2738 kc, but the Channel 30 antenna circuit is resonated for any one of the five frequencies to which Channel 30 may be tuned. This is accomplished by the user after the proper crystal selector knobs are set for the local Channel 30 frequency.

The Channel 10 and 20 antenna circuits utilize an inductively coupled antenna tank circuit so that the antenna may be voltage fed.

Micalex and Isolantite insulation is used wherever necessary to obtain the high insulation required on marine transmitting equipment. The oscillator, power amplifier, and antenna circuits are switched by relays controlled from the telephone dial at the local or remote control points.

Since the receivers must operate 24 hours a day, the receiving tubes use the ship's line voltage (110 volts d.c.) for power to all elements. The use of ship's power directly for the receivers and selective ringer is desirable in that rotating parts are reduced to a minimum. The transmitter motor generator operates only during communication periods which are normally of short duration. The motor generator supplies 6.3 volts d.c. for transmitter tube heaters and for relay coils energized during communication and 500 volts for the transmitter plate and screen supply. A motor starter is used so that the motor generator may be conveniently started and stopped from a remote point and to minimize the starting load on the ship's line.

The loudspeaker box is normally installed in the pilot house where incoming calls will always be heard by the officers on duty. The loudspeaker box contains the bell which is actuated by the selective ringer. The speaker is equipped with a volume control and a filter network which attenuates high audio frequencies, but permits the 300-cycle intership or shore station calling tone to be clearly heard.

The local and remote handset and control units are similar to ordinary land-line apparatus using an automatic dial. A volume control and a pilot light are mounted in the handset cradle. The pilot light indicates when the motor generator is running.

Manipulation of Equipment

Assuming the ship is in lower Lake Michigan, the Channel 30 transmitter and receiver crystal-selector knobs and the Channel 30 antenna tuning knob would be set for communication with station WAY and WAD. The equipment is now monitoring 2514 kc (WAY and WAD) 2738 kc (intership), 6470 kc (WMI) and 8585 (WMI). If the bell in the pilot house rings, or the ship's whistle signal is heard in the loudspeaker the captain, mate, or wheelsman lifts the handset from its cradle and replies on the channel indicated. The shore station normally identifies itself immediately by voice or by a tone and indicates by one, two, or three short tones which channel to use for the reply. When either the local or remote handset is removed from its cradle, the motor generator starts and the handset is connected to the output of all four channels. The loudspeaker is automatically disconnected from the circuit when either handset is in use.

If the call was from WAY, the ship operator would dial "3" which sets up the transmitting and receiving frequencies for Channel 30. The three receivers for Channels 10, 20, and 40 are automatically disconnected when "3" is dialed. The conversation is carried on much the same as in land-line communication except that it is not possible for either the ship or shore end to interrupt each other since when the ship is talking the ship receiver is deadened. Also, it is necessary to use voice-operated relays in the shore station to connect the incoming 2-wire land line to the 4-wire radio circuit leading to the transmitter and coming from the shore receiver. No trouble in carrying on a conversation is experienced by the conversationalists at either end of the circuit as soon as both realize that they must not talk at the same time. At the close of the conversation, the handset is replaced on its cradle, stopping the motor generator and returning the receivers to their monitoring condition as previously explained.

If the ship's crew hears their whistle signal on the loudspeaker, but no channel indication following the call, it means that another ship is calling on Channel 40. The handset is lifted from its cradle, the number "4" is dialed and the ship announces its name and asks who is calling.

If a ship desires to call another ship by the whistle signal system, the handset is lifted, and "4" is dialed. This sets up the transmitter for 2738 kc and disconnects receivers on Channels 10, 20, and 30, disconnects the loudspeaker and selector, and allows the dial to be used for making "longs" and "shorts" by dialing 8 and 2 as previously explained.

In any case, since recycling is automatic it is only necessary when transferring from one channel to another to "hang up" and dial the channel desired. The send-receive functions are automatic. The presence of voice in the microphone turns on the transmitter and deadens the receiver. After a cessation of voice, the transmitter is shut off and the receiver returns to full sensitivity. A small interval between words will not shut off the transmitter. This is done intentionally to allow a slight pause occasionally to avoid starting the transmitter carrier for each word since invariably a small part of the first syllable is lost.

REFERENCES

[1] "Federal Communications Commission Ship Power Hearing", Nov. 14, 1938, FCC document 30539.

[2] "Effect of Shore Station Location Upon Signals". R. A. Heising, *Proc. IRE*, Vol. 20, No. 1.

[3] "Report of Committee on Radio Wave Propagation". *Proc. IRE*, Vol. 26, No. 10.

[4] "North Atlantic Ship-Shore Radiotelephone Transmission, 1932-1933". C. N. Anderson, *Proc. IRE*, Vol. 22, No. 10.

[5] "Attenuation of Overland Radio Transmission in the Frequency Range 1.5 to 3.5 Mc." C. N. Anderson, *Proc. IRE*, Vol. 21, No. 10.

[6] "Report of Committee on Radio Wave Propagation." *Proc. IRE*, Vol. 21, No. 10 (Oct. 1933).

[7] "Ship to Shore Harbor Telephone Equipment." H. B. Martin, RCA REVIEW, July 1938.

[8] "Radiotelephone for Small Yachts." I. F. Byrnes, RCA REVIEW, Jan. 1939.

[9] "Special Temporary Rules Governing the Operation of Ship and Coastal-Harbor Telephone Stations in the Great Lakes Region, Effective March 31, 1939." FCC document No. 33190.