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R.C.A. SPECIAL NOTICES

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TO THE MEMBERSHIP:

This last meeting of the Club before the summer recess reminded one of the good old R.C.A. "ham" days when everybody gathered together in some member's radio shack and handed out the special "dope" on his own particular wonderful "hook up." Of course that was in the days before patent attorneys decided to run the radio game and shut off the information. However, here's hoping that in September when we resume activities again we will have more of these open "free-for-all" meetings, with everybody exchanging their own ideas of amateur construction and operation.

Although regular meetings will not be resumed before September, the Proceedings will continue to be issued as usual during the summer months.

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Navy Receiving Equipment

By L. C. F. Horle

Presented at meeting of the Radio Club of America, Columbia University, March 26, 1920

EVER since radio has been in the Navy, the Navy Department has carried on development work in its own organization and at the same time has used apparatus designed and built by commercial companies.

For its high power stations it has always and does still depend almost completely on the commercial radio companies for the design and manufacture of its equipment, but very early in the application of quenched gap transmitters to the Service it started its own development laboratories wherein research, design, and development were carried on in co-operation with radio manufacturers. This brought about a standardization that is essential to so large a military organization. The need for this will be readily understood when it is realized that both the Atlantic and Pacific Coasts have Navy Yards and Naval Stations at frequent intervals along their lengths and that these yards must be prepared, particularly in times of war, to make replacements in part or completely of all radio equipment. The additional advantages which lie in the fact that the standardization of apparatus results in multiplying the sources of supply and, usually, in the cheapening of the cost of production, have shown quite positively that the investment required for the establishment of radio laboratories and experimental manufacturing plants is well justified.

It was not until the recent European unpleasantness had taken on a serious aspect to ourselves that the problem of receiver design was seriously undertaken by the Navy Department.

Until late in 1916 the major part of the radio receiving equipment in use in the Navy was designed and manufactured by the commercial companies and it was said that there were about as many types of receivers as there were receivers in service. This of course led to tremendous confusion in the maintenance of this radio equipment and made operation of this equipment by the continually moving personnel of the Navy quite difficult. In addition to this the radio problems of the Navy are in themselves quite characteristic of only the Navy and were not well appreciated by the commercial designers of equipment. The tendency was, therefore, toward the establishment of a receiver design laboratory. Late in 1916 when funds were available the station at Washington Yard was made the residence of all receiver problems.

At that time the Navy was adopting the vacuum tube for general service use and was therefore confronted with the problem of making possible the use of the apparatus already in service with the tubes then available and the design of new and more efficient apparatus for operation with tubes.

The first design, which is in every detail the product of the Radio Laboratory, Washington Yard, is the SE-143 receiver. This was designed for reception on the wave lengths between 300 and 3000 meters of both damped and undamped waves.

The requirements to be met in the design of this receiver characterize all the design work that has been done in the service; that is, it is required of all receivers sent into the naval service that they have:

(1) A wide wave length range
(2) A high sensibility and selectivity
(3) Ease of operation
(4) Compactness and lightness in so far as it is compatible with the foregoing and with the conditions of transportation and storage of apparatus.
(5) Ease and cheapness of manufacture in quantity.

Probably the most difficult of these problems lies in the design of equipment of high selectivity and sensibility over a wide range of wavelengths. Since in all Navy apparatus continuous variation of wavelength is secured by the use of stepped inductance and continually variable air condensers, the problem reduces itself to the design of an efficient stepped inductance system, having a high inductance-resistance ratio for each step at the wave lengths at which that step is used.

The difficulty in securing a suitable value for this ratio lies in the space limitations which determine the size and distribution of the conductor comprising the inductance system and, hence, the dead-end effects which arise from this condition.

Fig. 1.
Interior View, SE-143.

This problem in general has been solved in two different ways and has given rise to two general types of receivers. The first of these is embodied in the type SE-143 receiver and those receivers developed on the basis of the SE-143 design. The second solution is typified by the SE-1420 receiver and those following it.

The SE-143 group is characterized in the electrical details of its design by the high values of the capacities of its tuning condensers and by the type of inductance systems used. In the mechanical details of its design it is characterized by the panel arrangements shown in the photographs, Figs. 1 and 2.

The controls for the antenna circuit inductance and capacity are located at the left, the controls for the secondary circuit inductance and capacity are located at the right, with the antenna coupling and tube coupling controls placed midway between these. A variable stopping condenser for use with the crystal detector is supplied with a control on the panel, as is the switch which makes possible the use of a crystal detector or vacuum tube detector. A buzzer and buzzer push-button are mounted on the panel for use in adjusting the detector.

Terminals are supplied for the connection of the antenna, ground, buzzer battery, crystal detector, loading coils in both the antenna and secondary circuits, and for the connection of the vacuum tube apparatus which will be described later.

The condensers as shown in Fig. 2 are supplied with metal dials, fastened to the shafts, which carry a wave length calibration from which the wave length of every possible combination of inductance and capacity is immediately evident. This is accomplished by the use of as many circular scales on the condenser dials as there are inductance taps. The index is caused to point to the proper scale by the action of the inductance switch through a rack and pinion. The inductance switch shaft carries a pinion in back of the panel which engages a rack to which the pointer is secured. Fine adjustment of the condensers is secured by means of a separate "Fine Adjustment" knob connected through a train of bakelite gears to a metal gear secured to the condenser shaft.

The coupling between the antenna circuit and the secondary is secured by means of a section of the primary inductance which can be rotated relative to the secondary. Connection to this moving coil is made through flexible conductors. One terminal of this coupling coil is connected directly to the ground terminal with the result that the capacitative coupling between the primary and secondary is kept low.

The inductances, which in their design details typify the first group of receivers, are bank-wound of a conductor of three groups of 10 strands of No. 38 enameled wire with double covering of silk, and are sectionalized. By this is meant the spacing between the three sections of the secondary and between the two sections of the primary. A cam carried by the inductance switch separates a series of contacts which break the connection between the used and unused sections of the winding for any position of the inductance switch. By this means dead-end effects are avoided and great wave length range made possible, in the first group of receivers.

A special inductance coil is provided

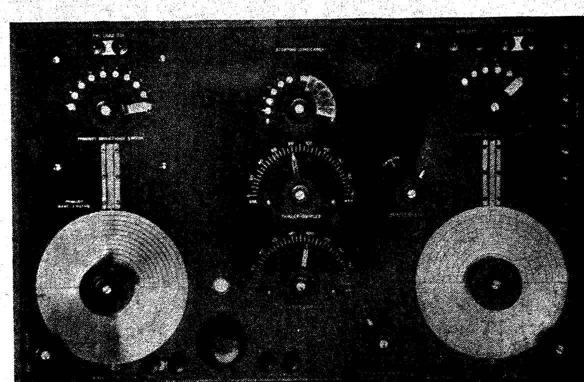


Fig. 2.
Standard Panel used on SE-952, SE-143, SE-1220, SE-712A

and mounted directly on the primary coupling unit for securing especially high values of coupling between the two circuits when the "Tuned-Untuned" switch is in the "Untuned" position. The function of this switch is to disconnect the secondary condenser and to connect the above mentioned inductance coil in series with the secondary inductance. This results in an untuned secondary system very closely coupled to the primary and is quite useful in picking up a station of unknown wave length in that it eliminates the need for the manipulation of the secondary condenser.

The tube coupling coil or "tickler" is mounted inside the secondary inductance coil and is rotated, as is the antenna coupling coil, by means of a link motion actuated by the coupling control knob.

Care is taken in the arrangement of the connecting wires to keep all conductors that are at high potential away from points of ground potential and to eliminate capacity coupling as far as possible by their careful location. In general this type of receiver is efficient, easy to build and to operate, and quite accessible for inspection and repair.

It is to be noted that only the tuning and coupling systems and switching mechanism are included in the receiver, the vacuum tube apparatus being supplied separately. This resulted from the fact that the major part of the receiving equipment in service previous to this model was designed for crystal operation only and hence requires the vacuum tube control apparatus to be separately mounted. In preparing this design it was, therefore, necessary to make operation, with the standard "Audion Control Box" possible. The unit is comprised of shock-proof vacuum tube receptacle, filament ammeter and rheostat, bridging condenser, grid condenser, switches for short circuiting the tickler winding and for transferring from plate supply storage battery to the usual ship's supply. A filter system consisting of two iron-core inductances and two paper condnsers is supplied for making possible the use of the ship's supply. Across this is connected a carbon sector potentiometer for the fine control of the plate supply voltage.

The next problem of importance came with the need for compact radio compass equipment for destroyers. As might be assumed from the size of this kind of craft, space is distinctly at a premium, so much so that special schemes and apparatus were necessary for radio operation on them. The radio compass equipment for destroyers was allowed even less space than the ordinary radio equipment since the use of compass equipment had not been contemplated in laying out this craft, with the result that an especially small receiver was designed to meet this need.

This is known as the SE-1012 receiver. The general panel layout of this receiver is quite similar to that established as standard in the previous types. It differs quite radically from the previous types, however, in that the vacuum tube and its associated controls are included in the receiver. A compass switch for disconnecting the antenna for bilateral compass operation and a "Tuned-Untuned" switch for pick-up work are supplied. An exceptionally compact crystal detector is mounted on the panel.

The tube coupling is perhaps the most novel part of the receiver in that it comprises both inductive and capacitative coupling. The coupling condenser in this receiver is of a particularly ingenious type. It consists of two circular plates separated by a bakelite ring, with a moving plate which through the motion of the coupling control may be moved toward or away from one of the stationary plates and hence away or toward the other plate. The moving plate is connected to the filament of the tube, while the two outer and stationary plates are connected to the terminals of the tuning condenser and to the plate and grid of the tube. This arrangement constitutes an extremely ingenious method of varying the potential of the filament relative to the grid and plate.

This type of receiver was built in great numbers and installed on destroyers. The difficulties of undamped reception on such wave lengths as this receiver was designed for brought a new problem. It became necessary to adopt some method other that the ordinary "beat reception" method for this work since the change in capacity of the oscillating circuit with the motion of the operator's hands in the vicinity of the receivers of the early type was quite sufficient to cause the beat note to pass into inaudibility when his hands were removed from the condenser knobs. To eliminate delicacy of heterodyning on short waves the rotary tone condenser was devised. This in its essentials is merely a rapidly varying capacity which may be connected across the secondary circuit of the receiver and hence in parallel with the tuning condenser. In brief its operation is this: If resonance is established between the antenna circuit and the secondary circuit with the "Rotary Tone Condenser" at rest and at its mean value and if, then, the tone condenser is caused to rotate, it detunes the circuit at a frequency determined by the speed and the number of complete cycles of capacity variation per revoution. In the Type 999 rotary tone condenser these capacity variations are accomplished by a toothed rotor and stator. The rotor, however, rotates near a stationary disc, being separated from it by a very short distance. The terminals of the device are connected to the toothed stator and the fixed disc and the capacity, therefore, resides in the space between the rotor and stator and between the rotor and the disc. By this means a rapidly varying capacity may be secured without resorting to moving contacts. A loop and an antenna are used, the loop being connected in series with the secondary inductance. Thus when the antenna is used unilateral operation is possible; that is, both the sense and direction of the signal wavefront may be determined, while with the antenna disconnected by means of the compass switch only bilateral operation is possible; that is, when the direction of the signal wavefront or the bearing of the transmitter can be determined.

Under the able direction of Prof. Hazeltine, who was then connected with the Navy Dept. in a consulting capacity, much research was done before the actual design was started and the various developments of this research were incorporated in the SE-1420 receiver.

In the design of this receiver effort was made to secure wide wave length range, high selectivity, freedom from local interference, stability in regenerative amplification, simplicity of operation, compactness, durability, and cheapness of construction.

In conformity with established practice,

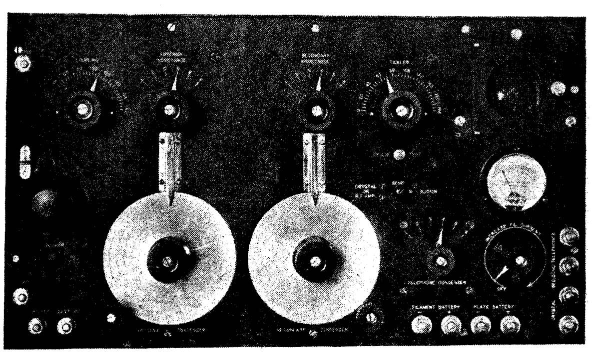
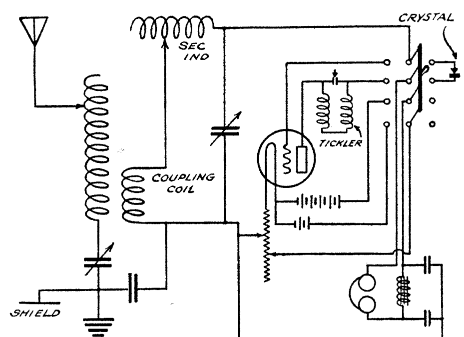


Fig. 3.
Panel View, SE-1420.

both tuned circuits have inductance coils provided with taps, six in number, and continuously variable air condensers giving overlapping wave length ranges from 260 meters up to 6,000 meters when the capacity of the antenna is .0004, and up to 7500 meters when the capacity is .0009 microfarad. The practice of sectionalizing and disconnecting the unused portions of the windings to avoid "resonant coils" has been abandoned, the windings being now made continuous and merely short-circuited at the proper taps. This completely eliminates "resonant coils" and allows of a simple and rugged construction. The arrangement is such that the coupling between the short-circuited and the active portions of the coils is loose, so that little loss is introduced.



SE-1420 RECEIVER

The chief factor contributing toward high selectivity in this receiver is the choice of a higher ratio of inductance to capacity than has hitherto been customary; the antenna condenser having a capacity of .0015 microfarad, and the secondary condenser of .00075 microfarad, whereas the type SE-1220 and other receivers of similar wave length range had capacities of .005 and .003 microfarad respectively. Compactness and proper distribution of winding spaces are secured by reducing the size of the Litz wire used to 20 strands of No. 38 wire and by winding the successive taps in increasing numbers of banks.

Interference from short-wave nearby stations and from transmitting apparatus in close proximity to the receiver is eliminated by the use of grounded sheet-copper shielding completely enclosing and separating the antenna and secondary circuits. To completely eliminate capacity coupling, the coupling coil is provided with a novel electrostatic shield consisting of an additional winding placed over it, the capacity current in this winding inducing in the coupling coil voltage which exactly neutralizes that resulting from capacity current in the coupling coil. The coupling coil is placed in the secondary circuit instead of in the antenna circuit chiefly for the purpose of obtaining sufficient coupling without the use of taps to secure the low wave lengths, as the inductance of the antenna would otherwise prevent this. To secure complete stability in regenerative amplification, the stopping condenser and grid leak are discarded, and the grid is connected through the secondary inductance to a point on the filament rheostat selected to give a negative grid potential or "bias" of about 1.3 volts with a Type SE-1444 tube, and about 2.2 volts with a Type CW-933 tube.

Oscillation control over the entire wave length range with both types of tubes above mentioned necessitates a large tickler, and in order to avoid resonant effects from this tickler at the shortest wave lengths, it is made in the form of a variometer, having a stationary part wound alongside of the secondary inductance coil, and allowing the plate circuit to be tuned.

The difficulty which frequently arises in short wave heterodyne reception from the capacity between the operator's hand and the secondary circuit (which may change the note sufficiently to make it inaudible) is eliminated by the use of an audio frequency choke coil and telephone condenser which prevents radio-frequency current from reaching the telephones.

The receiver permits the use of either the crystal or the vacuum tube detector, and contains within itself the receptacle and controls for the latter. The terminals of the secondary circuit are brought out for connection to a radio-frequency amplifier when the crystal-audion switch is thrown to the left. The standard auxiliaries, such as the filament ammeter, test buzzer, push button, etc., are clearly shown in the photograph, Fig. 3. The construction is simplified and cheapened by the introduction of unit assemblies, enabling the separate elements of the apparatus to be assembled independently instead of being built into a single panel.

Following the design of the SE-1420 receiver came the need for a radio compass receiver of greater selectivity and sensibility than had been available previously. The use of unilateral operation has been abandoned because of the difficulty in securing reliable bearings with the personnel available for operating the equipment. The possibility of using radio frequency amplification for this type of radio reception was investigated but it seemed evident while this investigation was being made that high power audio-frequency amplification would best meet the service needs, particularly since there was evidence at hand indicating that greater precision of bearing determination could be made if reception was done with the tube in oscillation. On the basis of this data the SE-1440 receiver was designed.

A series of amplifiers has been developed at the Radio Laboratory that should meet the needs of the service very satisfactorily. They are designed (1) to supply moderately high audio-frequency amplifications where conditions are such that an ordinary antenna is available, or (2) to supply high audio-frequency amplifications where low antenna or loop reception is to be done over a great range in wave lengths, or (3) to supply high radio and audio-frequency amplification where extremely high amplifications are necessary and where the range in wave lengths is not greater than three to one.

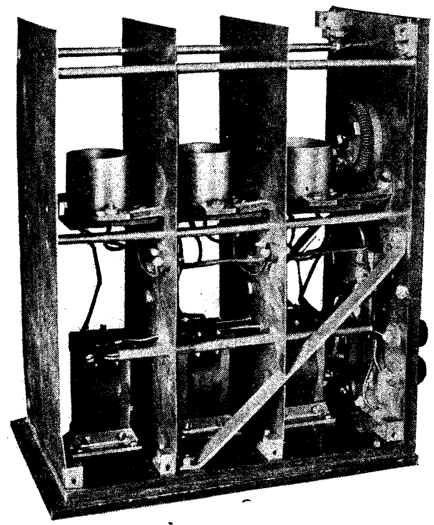


Fig. 4.
Three Step Audio Amplifier
(Electrcally Shielded). SE-1599.

For use under conditions specified in (1), the SE-1600-A amplifiers are well suited. These amplifiers use two of the SE-1444 or CW-933 (Western Electric "J") tubes in connection with the two audio-frequency transformers.

The SE-1600-A uses iron core transformers. The coils of the transformers are machine wound with No. 44 copper wire. The layers are insulated from each other by means of paper and the whole coil impregnated with wax. The primary consists of 3900 turns and the secondary of 12,000 turns, the ratio being somewhat greater than three to one. The core is built up of 5-mil silicon steel. Three telephone jacks are provided by means of which the telephones may be connected in the plate circuit of the detector tube or in the plate circuit of either of the amplifier tubes.

For use under conditions outlined in (2) the SE-1599 amplifier has been designed. (Fig. 4). This amplifier consists of three amplifying tubes and three amplifying transformers of the audio-frequency type. The whole device is thoroughly shielded and every means adopted to make it free of disturbance due to interactions in itself or between it and other apparatus. It is designed to meet the need for very high amplifications where a wide range in wave lengths is essential. As such it is suited for operation with receivers supplied with "audion control boxes" or with receivers equipped with vacuum tube detectors. A two point telephone switch provides for cutting out the last stage of amplification when necessary. Further control of the amplification may be accomplished by adjusting the filament rheostat.

For use under the conditions outlined in (3) the SE-1611, SE-1613, SE-1615, and SE-1617 amplifiers have been designed. These amplifiers are of the radio-audio-frequency type and employ six SE-1444 tubes. Iron core transformers are used for both the radio and audio frequency amplifications. The radio frequency transformers are the only major details in which these amplifiers differ from one another, each amplifier having its transformer designed for maximum amplification over a definite range of wavelengths.

The ranges of these amplifiers are approximately as follows:

SE-1611	400 to 1000 meters
SE-1613	1000 to 3000 meters
SE-1615	3000 to 10000 meters
SE-1617	6000 to 20000 meters

In addition to the above series of amplifiers there have been several types of amplifiers designed for special applications. The most interesting of these is, perhaps, the SE-1493. This amplifier consists of 4 tubes and three radio-frequency transformers having a range of 400 to 1,000 meters. The last tube of the series acts as a detector. It is designed to meet the need for radio-frequency amplification of this range where audio-frequency amplification in the form of the SE-1600 is already available and requires no "audion control box" for its operation.

This covers in general the trend of Navy Receiver development and illustrates the variety of apparatus required to meet the growing need of the service for special designs and purposes. No attempt has been made to emphasize the tremendous efforts necessary to perfect each detail under pressure of war conditions but the results of the work well justified this careful development.