Communications Review

It is intended in this series of articles to review the present state of Naval Radio Communication and to indicate whenever possible the trend of development. The articles will not be confined to descriptions of equipments but will describe, as may be necessary, Communication Systems and Communication Circuits. In this first article of the series it is hoped to present an overall picture, the details of which will be filled in in future articles.

When designing any radio communication circuit we must provide for and consider the effect of all the following factors :—

(a) *A source of radio frequency energy—the transmitter.*

(b) *The means of impressing intelligence on the source—modulation.*

(c) *A radiator of radio frequency—transmitting aerial.*

(d) *The means of transferring the energy from the transmitter to the aerial.*

(e) *The laws governing the propagation of radio frequency energy to a distance.*

(f) *A collecting system—the receiver and its aerial* ; *and*

(g) *The effect of local conditions at the receiver.*

Before describing the Naval communication circuits as they exist it is well worth while to summarise as briefly as possible the known laws of propagation of radio frequency energy.

(i) *Very Low (below* 30 *Kc/s.) and Low Frequencies* (30-300 *Kc/s.*).

The ground wave travels with comparatively small attenuation up to distances of 1,000 miles and the range depends on the power radiated and is practically independent of diurnal, seasonal or annual variations. The sky wave is very important for very long ranges. The energy is refracted back to the earth after only slight penetration into the ionosphere and so the energy is only slightly attenuated.

(ii) *Medium Frequencies* (300 *Kc/s.*-3,000 *Kc/s.*).

In this frequency band the ground wave suffers greater attenuation than at lower frequencies, the attenuation increasing rapidly at the higher end of the band.

Reliable ground wave ranges of 50-100 miles can be expected. During the day the sky wave is almost completely absorbed, but at night it is reflected and gives greater ranges. In the region between purely ground and purely sky wave transmission the sky wave may be comparable in intensity to the ground wave and interference of the two gives rise to continuous variation of field strength.

(iii) *High Frequencies* (3-30 *Mc/s.*).

In the H/F band, the ground wave is useful only for transmission over relatively short distances due to the greatly increased attenuation at these frequencies. Sky wave transmission is very important for long-range communication up to distances of several thousand miles. Sky wave transmission is due to reflection from the ionosphere and depends on the intensity of ionisation and the height at which reflection takes place. The optimum frequency to use varies during the day and according to the direction of the transmission ; it also varies with the season and from year to year.

(iv) *Very High Frequencies* (30-300 *Mc/s.*).

In the V.H.F. frequency band transmission takes place chiefly by means of the ground wave. Frequencies of 30-50 Mc/s. are at times reflected, giving rise to greater ranges, but the conditions favourable to such reflection are so spasmodic that it is useless to take advantage of them when formulating a communications system. In this band reliable communication is normally limited to within or slightly beyond the optical range. Optical range in land miles $= 1{\cdot}22\,(\sqrt{h_1} + \sqrt{h_2})$ where h_1 and h_2 are the heights of the transmitting and receiving aerials in feet above mean sea level.

The radio noise conditions existing at the receiver have a very marked effect on the received field strength necessary for good communication. The lower the noise level the lower the field strength needs to be and, all other factors being equal, the less power need be radiated to establish reliable communication.

In the above paragraphs the International system of frequency classification has been used, but in later paragraphs, particularly those describing equipment, the older classification may be used, e.g., Type 601 transmitter covering the frequency range 1·5 to 24·0 Mc/s. is classified as an H/F. transmitter, whereas under the modern classification it covers part of the M/F. band and part of the H/F. band. To avoid confusion on this point the older classification is given below and this can be compared with the present-day classification as given above.

Low Frequencies L/F.—Below 100 *Kc/s.*
Medium Frequencies M/F.—100-1,500 *Kc/s.*
High Frequencies H/F.—1·5-30 *Mc/s.*
Very High Frequencies VH/F.—Above 30 *Mc/s.*

Naval radio communications can be divided into the following sub-divisions :—

(a) *Fixed services.*
(b) *Shore—ship.*
(c) *Ship—shore, ship—ship, and ship—air.*

and although to many readers some of the following review may be only of academic interest it is hoped to make it sufficiently broad to give a complete picture with due consideration to all the factors involved.

Fixed services are, as the name implies, communication services between Point A and Point B. They are all operated by sky wave high-frequency radio energy, the frequency being changed according to the ionospheric conditions existing over the path. For a continuous twenty-four hours service this may mean two or three changes of frequency during the twenty-four hours. These frequencies may also have to be changed according to the time of year, *i.e.*, summer or winter. The transmitters are all crystal controlled, spot frequency, with several amplifier stages, and deliver from 3 to 25 kilowatts of energy to the aerial. The aerials are designed for a given frequency and for the correct radiation pattern, *i.e.*, maximum radiation in the required direction. The aerials may be sited some distance from the transmitter and the power is fed to the aerial via open wire twin feeders or by concentric cable feeders. At the receiving stations the aerials are designed for the frequency in use and the direction of incoming signals. The principle of space diversity, *i.e.*, two or three aerials spaced a few wavelengths apart, is used to overcome fading.

The intelligence is impressed on the radio frequency carrier by the system of morse "on-off" keying generally at high speed, up to 120 words per minute.

These stations, both transmitting and receiving, require a fairly large area of land approximately one thousand yards square, and the noise level at the receiving station should be as low as possible, so they are usually situated some distance from the Headquarters they are intended to serve and are linked to the Headquarters by land lines. In cases where the H.Q. is required to control several transmitters or receive messages from several different circuits, "voice frequency" carrier equipment is installed so that several keying circuits can be carried simultaneously on the one physical pair of lines.

Commercial equipment is used since the requirements for these fixed services are very similar to those for commercial fixed services.

For diversity reception the Marconi Type CRD 150 receiver is used. This consists essentially of three superheterodyne receivers, with a common first heterodyne which is controlled in frequency by a quartz crystal oscillator, and the necessary apparatus to convert the output signal, which is the sum of the three signals received, to direct current, this in turn is converted to tone signals for transmission to the remote Headquarters via the voice frequency equipment. For single aerial reception the receiver B28, which is described later, is used.

During the war some W/T base ships were fitted with the equipment so that they could act as mobile stations for fixed communication services as the need arose, the reduction in efficiency owing to restrictions imposed on the design of the aerial had to be accepted.

Experimental development in the use of teleprinter systems for fixed services or, as it is usually called, automatic telegraphy is in progress and a number of services are now using teleprinters and the conversion of all fixed services to teleprinter working is envisaged.

Shore-ship communications are mainly carried out by area broadcasts. The transmitting station sends out the message simultaneously on one low frequency and one or more high frequencies, depending on the position and extent of the area which has to be covered. By careful choice of frequencies and power it is possible to so interlock the coverage areas of each frequency to give complete continuous coverage for the area. During the war VL/F transmissions from the U.K. were used during stated times of the day to fill in some awkward gaps in the coverage.

Since the transmission is intended to serve an area it is not possible to use highly directive aerials as in the fixed series. There is, however, sufficient area available to erect efficient L/F and H/F aerials. For H/F, vertical quarter wave aerials, end fed, and cut to frequency are used.

The intelligence is impressed on the carrier by morse "on-off" keying at hand speeds, C.W. or M.C.W. may be used.

Table I gives details of the transmitters which are in general use both for fixed and shore-ship circuits. The L/F transmitters are master oscillator controlled, with several stages of amplification. Control of the frequency by quartz crystal oscillator is preferred for the H/F transmitters but master oscillator is also provided to enable the transmitters to work on frequencies for which a crystal is not available.

TABLE I.

TRANSMITTERS FOR FIXED AND SHORE-SHIP COMMUNICATION CIRCUITS.

Type No.	*Frequency Range.*	*Output Power to Aerial.*
Standard Telephones & Cables Co. C.S. 3B	3-21·5 *Mc/s.*	5 *Kilowatts.*
Standard Telephones & Cable Co. C.S. 5B	12·0-30·0 *Mc/s.*	10 *Kilowatts.*
Marconi S.W.B.8	2·0-2·6 *Mc/s.* 3·0-21·4 *Mc/s.*	2·5-3·5 *Kilowatts.*
Marconi S.W.B.10	3·0-22·0 *Mc/s.*	25 *Kilowatts.*
Marconi S.W.B.11	3·0-22·0 *Mc/s.*	6-7 *Kilowatts.*
Marconi TFL76/1A	40-150 *Kc/s.*	40 *Kilowatts.*
Standard Telephones & Cables Co. C.M.8.A.	60-500 *Kc/s.*	10 *Kilowatts C.W.* 7·5 *Kilowatts M.C.W.*
Standard Telephones & Cable Co. R.20.A.	100-500 *Kc/s.*	5 *Kilowatts.*

For ship-shore and ship-ship communications at ranges greater than optical H/F is generally used, and on occasions becoming increasingly rare L/F and M/F. For ranges less than optical VH/F or H/F is used. For ship-air, VH/F is now always used when communicating with single-seater aircraft, but H/F is used for ranges greater than optical for communication to reconnaissance and other planes carrying a W/T operator.

Thus a ship has to receive transmissions from 16 Kc/s. to 156 megacycles and to transmit on frequencies from 275 Kc/s. to 156 megacycles. The number of circuits for which provision is made varies according to the class of ship and the following examples will give some idea of the scope of the ship communications :—

Type of Ship Aircraft Carrier	Circuit	Type of Ship Destroyer
10	*H/F Transmission* R/T and W/T all power.	3*
10	*H/F Reception*	3 bays.
1	*L/F Reception.*	1 bay.
4	*Broadcast Reception.*	1 bay.
2	*M/F Transmission W/T.*	1*
16	*VH/F Transmission.*	7
16	*VH/F Reception.*	8
1	*M/F D/F.*	1
1	*H/F D/F*	Selected ships.
1	*VH/F D/F.*	0
1	*UH/F D/F*	Selected ships.

**The M/F circuit is alternative to one of the three H/F.*

Before describing the equipment which is fitted, a few of the problems of ship radio communications will be discussed.

To provide the required number of efficient receiving and transmitting aerials is probably the most pressing problem. It must be remembered that in addition to the communication aerials, sites have to be found for radar aerials and aerials required for direction finding and navigational aids. The design of modern ships with low masts and masts close together, adds to the difficulties of the problem.

For simultaneous transmission and reception separate aerials have to be provided for the transmitter and the receiver, and the transmitting aerials have to be grouped together and separated as far as possible from the receiving aerials. Prior to the war certain rules had been formulated, as the result of a considerable amount of experimental work, as regards the minimum separation in space and frequency required for simultaneous transmission and reception. These figures were obtained with the equipment then in use. During the war operational needs caused many infringements of the general principle of grouping and separation of the aerials and the problem requires re-examination in the light of the introduction of VH/F and the considerable reduction in the number of M/F circuits. For simultaneous transmission and reception on VH/F circuits the aerials must at present be separated by at least 15 feet and the frequencies by 2 Mc/s.

The VH/F and H/F aerials must have all-round radiation or reception, *i.e.*, must be non-directional. On board ship the numerous metal structures and wires may resonate and cause considerable departure from the ideal. VH/F aerials are sited as high as possible in order to obtain the required range, but even so the radiation pattern is seriously affected by other aerials, masts and stays.

The grouping of the transmitter aerials brings in its train a serious disadvantage when the aerials have to be very close to one another, *e.g.*, in an aircraft carrier ; for in these circumstances an appreciable degree of mutual coupling will exist and the tuning of one aerial will depend on the frequency to which the other is tuned.

Low and Medium frequency transmitting aerials usually consist of two or three wires spaced 3 feet apart and slung between the masts to form an inverted L. The length of the roof, *i.e.*, the horizontal part, is of the order of 50 ft. and the vertical portion is 50 ft. The aerial is connected to the output of the transmitter via an 18-inch trunk consisting of an outer sheet-metal structure usually of D-shaped section with an inner copper conductor spaced from the outer by insulators. Owing to the low effective height and shortness of the roof the M/F aerial is not very efficient. For reception on these frequencies single-wire aerials either vertical or near vertical are used.

In H/F transmissions single-wire vertical or near-vertical aerials are used which are easy to rig and easy to maintain. They may vary in length from 45 to 100 feet or more and have an electrical length varying from a fraction of a wavelength to several wavelengths. In brief, they are most inefficient and the use of single-wire aerials of any length, coupled with the method of feeding the aerial from the transmitter via 8-inch trunks similar in construction to the 18-inch trunks described above, adds considerably to the complexity and size of the transmitters themselves and results in overall efficiencies of the order of 10% or less, *i.e.*, with a transmitter capable of delivering 100 watts in general not more than 10 watts is radiated.

For H/F reception single-wire aerials are used. When the foot of the receiving aerial is a considerable distance from the receiver, concentric feeder cable is used to connect the two and a transformer is inserted at the foot of the aerial to match approximately the impedance of the aerial to the impedance of the feeder cable (100 ohms).

To cut down the number of receiving aerials and add to the overall flexibility of the M/F and H/F circuits, the receiving aerials are connected in the receiving office to an aerial exchange by which any aerial may be connected to any receiver.

For VH/F circuits the aerial problem in some respects is much easier ; these circuits usually operate on comparatively narrow frequency bands and a half-wave dipole centre fed is of such a size that it can be made from two quarter-wave self-supporting metal rods connected to a central junction box. The impedance of such an aerial is sufficiently close to that of a half-wave aerial, over a narrow band of frequencies, that it is possible to couple aerial to transmitter by a concentric feeder cable without risk of voltages in excess of the permissible value being impressed on the feeder cable.

Having painted a somewhat gloomy picture of the aerial problem, it is only fair to add that the serious nature and difficulty of the problem are clearly realised in both technical and applicational communication circles, and considerable effort is being expended on finding the solution. It may be that the solution will involve changes in organisation. In the meantime the aerial rig of all new construction vessels is carefully considered in A.S.E. at a very early stage and the aerial rig decided upon can be regarded as the most efficient compromise between the somewhat " warring " factors that it is possible to obtain.

As regards H/F aerials the introduction of whips will give some easement in certain directions. The whip aerial consists of a self-supporting metal rod, insulated from earth at its base, it requires no top support and can be sited in positions away from the mast. but the length is very limited, 25-35 feet, and if required as a permanent structure the weight is considerable (2 cwt. including base support). Emergency whips are considerably lighter, but they will not stand up to all the conditions which may be met in service.

For the VH/F aerials the system of Common Aerial Working which has recently been evolved in A.S.E., and is now being fitted, effects considerable easement to the problem. Up to six transmissions may be made simultaneously on one transmitting half-wave dipole and six lines of reception can be carried out simultaneously on one receiving half-wave dipole. The cost is a reduction in radiated power for each individual transmission from the theoretical maximum. This reduction is usually offset by the practical consideration that it is easier to find a good site for one aerial than for six.

Reference has been made above to the minimum separation in space between transmitting and receiving aerials and the frequency separation between transmitting and receiving frequencies which have been found to be necessary for simultaneous transmission and reception using M/F and H/F frequencies. It is assumed that the transmitters are adequately screened and that no radio frequency energy is fed to the receiver other than via the aerials. With segregated transmitters and receivers in completely screened offices this is fairly easy to realise as any inter-connecting wires can be filtered, but the introduction of even low-power transmitters in the receiving room creates a very different problem unless the transmitter and associated aerial leads in the office are completely screened. So far no low-power transmitter has been developed which can be fitted with impunity in a receiving room.

Non-radio electrical equipment is being fitted in ships in increasing quantity. Much of this equipment is a potential source of interference to communication circuits. Anti-interference devices, generally a combination of filters and screening have had to be fitted to such equipment as close to the source of interference as possible.

The advent of radar increased the complexity of the interference problem. The interference arises from three main sources.

(a) *Break through of the carrier frequency of the radar pulse.*

(b) *Direct reception of the lower frequency components associated with the radar modulator and*

(c) *Spark generated frequencies in any part of the radar aerial system.*

(a) could be avoided by additional preselectivity at the receiver, but (b) could only be cured at the transmitter. The high-frequency components of the pulse modulation which occur over the whole band in varying amplitudes depending on the steepness of the pulse shape were, in these early radar transmitters, radiated from the open aerial feeder, from the aerial itself, directly from the modulator panel and from all leads running therefrom. The same remarks apply to (c), which may be caused either by under-designed insulation or by any non-linear device such as a transmit/receive switch in the radar aerial circuit.

The problem was first tackled by deliberately shutting down the receiver in synchronism with the radar pulse. The apparatus was fitted as an attachment to the existing receivers. This scheme is limited in application and was successful only in certain cases and has been superseded by the incorporation of diode limiters in the receivers. In parallel with the fitting of anti-interference devices in the receivers steps have been taken to reduce the radiation on all frequencies outside the bandwidth necessary for the system and in certain cases radio frequency filters have been fitted in the radar aerial systems.

In addition, considerable interference has been caused by incomplete screening of the radar transmitter and its associated modulator. In some cases the modulator is some distance from the transmitter and the cable carrying the modulation has been a very active source of interference.

Interference to radar systems by communication transmitters may be serious due to the radiation of harmonics and as the radar receivers are easily saturated serious interference is caused at a relatively low level.

The cure for all interference, except of course that due to radiation on the wanted frequency, is to suppress all radiation on unwanted frequencies at the source.

Transmitters, both radar and communication, must be adequately screened and filtered, and all cables carrying radio energy must be screened. In practice it is uneconomic to reduce the unwanted radiation below a certain minimum, and receivers—both communication and radar—must be designed to cope with this minimum by providing sufficient R/F selectivity and adequate limiting devices. With this end in view a comprehensive anti-interference specification is being prepared to cover all radar and communication equipment and the methods of fitting it on board.

A form of interference met with in VH/F communication which severely restricts the choice of VH/F frequencies that can be used in any ship has recently been brought to light in A.S.E. and has been called the " rusty bolt " effect. It was observed that two VH/F transmitters on, say, 100 and 110 megacycles, did not individually interfere with a receiving channel on 120 megacycles but that when operated simultaneously there was severe interference. The interference was due to the mixing and rectification of the second harmonic of one transmitter and the fundamental of the other. (2 × 110 100 120.) The necessary rectifier is unfortunately always present in the shape of a point contact of dissimilar metals, or even rust and a metal which behaves exactly the same as the " cats whisker " crystal detector of the " pre-valve " age in wireless, and there is nearly always a useful radiator in the form of a suitable length of metal attached to this detector. If the aerial rods of the receiver are not securely fitted they themselves may provide the necessary rectifier.

For efficient communications it is essential that the transmitter and receiver are adjusted to the required frequency and do not drift from that frequency during the message. In practice it is fairly easy for the receiver to search a narrow band of frequencies but this involves skilled operators on every circuit and in war time skilled operators in the numbers required are just not available.

For communication circuits using L/F and M/F frequencies the problem is not very difficult technically. The transmitter requires a well-designed master oscillator and the receiver, provided that care is exercised in the choice of components, will remain on frequency. In general these transmitters are not calibrated directly in frequency but are set to frequency by wavemeter. The older receivers are not calibrated directly in frequency and have to be set by a wavemeter. The later ones are calibrated directly in frequency but the calibration requires frequent checking.

The problem of frequency stability for high-frequency transmitters is much more acute. Transmitters, as regards frequency stability, can be classified as follows :—

(a) *Self-excited*—frequency stability very poor and such transmitters must be considered as obsolete.

(b) *Master Oscillator*—in general it is impossible to attain the frequency stability required by a non-temperature-controlled master oscillator, but the Americans by temperature control and careful choice of components have achieved a high degree of stability.

(c) *Crystal Control*—control of the frequency by quartz crystal oscillators yields the highest degree of stability as yet achieved, but a crystal is required for each frequency. Crystal control on spot frequencies is used almost entirely in ship-to-air communications and with ship-ship inter-communications such as Convoy R/T circuit where loudspeaker watch is required for long periods without the possibility of checking the frequency.

(d) *Partial Crystal Control*—by building up the required frequency from a harmonic of a quartz crystal oscillator and a variable frequency oscillator, it is possible to achieve quite a high order of frequency stability yet use only one crystal, and be able to tune continuously over the entire frequency range. This scheme is adopted in Type 57 CHR and in the 601/5 transmitters.

H/F receivers are usually calibrated directly in frequency, but the calibration requires frequent checking. The transmitters and receivers for VH/F circuits are invariably crystal-controlled.

The increase in quantity and complexity of radio communication has emphasised the problem of maintenance. It must be remembered that a ship must of necessity be largely self-supporting in this matter and certain items of test equipment essential for proper maintenance are gradually being supplied.

Some details of the equipment which is at present fitted is given in the Table II. Transmitters covering the H/F and M/F frequencies may be roughly grouped into (a) *High Power* (1·0 *k.w. or above*); (b) *Medium Power* (100-400 *watts*); *and* (c) *Low Power* (*less than* 100 *watts*). The high-power sets are normally used for long-distance ship-shore and ship-ship communications, the medium-power for ship-shore and ship-ship communications (in cases where space is not available for the high-power sets), and for ship-air communications when using H/F. The low-power sets are normally used for ship-ship communications and ship-shore when their range is sufficient. This is a very broad generalisation, since it is obvious from the paragraphs on the propagation of H/F radio waves that long-distance communication can be established using low-power transmitters when the ionospheric conditions are favourable.

Considerable care is necessary when quoting figures for the power of an H/F transmitter. The essential figure is the power radiated, but with wide frequency range transmitters working into varying lengths of trunk and aerial it is impossible to quote a single figure to cover all cases. Recourse has to be made to the power which is available and, as already stated, 10% or less of this is radiated.

The H/F transmitters are designed to cover a very wide range of frequencies. This gives the required degree of flexibility in the choice of frequency to be used but, coupled with the wide limits of aerial and trunk with which the transmitter may be connected, adds considerably to the complexity and size of the transmitter. In practice the frequency that may be used for any given communication circuit is limited, by organisation factors, to quite a small number of frequencies scattered at fairly wide intervals throughout the range. The final choice of frequency depends on the relative position of transmitting and receiving stations and on the ionospheric conditions. To assist in the choice of frequency to be used optimum H/F frequency guides are published quarterly. This publication, known as M 350, is based on forecasts of the ionospheric conditions which can be expected for the various localities at various times of day and night.

All VH/F transmitters are crystal-controlled and employ several stages of frequency multiplication to derive the final frequency from the quartz crystal oscillator, since crystals with a fundamental frequency higher than 10 Mc/s. are not a practical proposition. The maximum power at present used is 50 watts and with vertical half-wave dipole aerials efficiencies of the order of 70% are obtained. Many of the reports of poor VH/F ranges are undoubtedly due to faults in the feeder plus aerial which give rise to losses and reduce the power radiated. These faults generally occur in the junction and termination boxes and not in the feeder cable itself.

Morse keying at hand speeds, using either C.W. or M.C.W., is used at present for long-range ship-shore and ship-ship communications. For short-range communications ship-shore, ship-ship, ship-air R/T is being increasingly used. The older receivers covering 15-550 Kc/s. consist of one or two stages of R/F amplification, a detector followed by one or two stages of audio amplification and a local oscillator for receiving C.W.

Superheterodyne receivers are generally used for H/F reception and always used for VH/F reception. The special factors to be considered in receivers are :—

(a) *Accurate frequency calibration and good frequency stability.*

(b) *Means of eliminating interference. This is usually met by good H/F selectivity and the incorporation of a limiting device.*

(c) *The prevention of radiation from the receiving aerial, otherwise the switching on of the receiver is sufficient to break W/T silence.*

The requirement as regards accurate frequency calibration and frequency stability is met in the case of all VH/F receivers by using a quartz crystal oscillator with the necessary frequency multiplying stages for the first heterodyne. This is also done in some of the H/F receivers associated with crystal-controlled low-power transmitters in order to maintain loudspeaker watch and reduce the number of skilled operators required.

TABLE 2.

DETAILS OF EQUIPMENT AT PRESENT FITTED.

N.B. A.1.—C.W. A.2.—M.C.W. A.3.—R/T.

M/F TRANSMITTERS.

Type	*Where fitted*	*Frequency Range*	*Wave form*	*Power to aerial*	*Type of drive*
59*D*	*Main and 2nd offices of Cruisers and above.*	100-500 *Kc/s.*	*A.1.* *A.2.*	4,000 *w.*	*Master oscillator continuous frequency.*
American TAJ	*Main M/F transmitter in Fleet destroyers and certain other vessels.*	175-600 *Kc/s.*	*A.1.* *A.2.*	500 *w.* 250 *w.*	*Master oscillator.*

TRANSMITTERS COVERING BOTH M/F AND H/F. FREQUENCIES.

49/*M*/*MR*	*Main set in destroyers and certain sloops.*	100-500 *Kc/s.*	*A.*1. *A.*2.	750 *w.*	
		2-19·0 *Mc/s.*	*A.*1. *A.*2.	250 *w.*	*Self-excited.*
	4 *T attachment*	100-500 *Kc/s.*	*Spark*	50 *w.*	
		100-17,200 *Kc/s.*	*A.*1. *A.*2. *A.*3.	20-7 *w.*	*Crystal or master oscillator (continuously variable in frequency)*
50/*M*/*MR*	*Main set in mine sweepers.*	100-1,700 *Kc/s.*	*A.*1. *A.*2.	250 *w.*	*Self-excited.*
		100-1,700 *Kc/s.*	*A.*2.	20 *w.*	*Self-excited.*
		3-18 *Mc/s.*	*A.*1.	150 *w.*	*Self-excited.*
		100-17,200 *Kc/s.*	*A.*1. *A.*2. *A.*3.	20-7 *w.*	*Crystal or master oscillator (continuously variable in frequency)*
51	*Low-power set in cruisers and destroyers.*	150-1,800 *Kc/s.*	*A.*1. *A.*2.	50 *w.*	*Self-excited.*
		1,670-13,600 *Kc/s.*	*A.*1. *A.*2.	25 *w.*	*Self-excited.*
55*M*	*Main set in submarines.*	1·5-3·0 *Mc/s.*	*A.*1.	15·0 *w.*	*Master oscillator (continuously variable in frequency).*
		3-180 *Mc/s.*	*A.*2. *A.*3.	2,000 *w.*	
60 *DR.*	*Lower power mains-operated or battery-operated in corvettes and above.*	100-17,200 *Kc/s.*	*A.*1.	30 *w.*	*Crystal or master oscillator (continuously variable in frequency)*
60 *FR*				8 *w.*	
60 *EQR*				8 *w.*	
607 607 *E* 607 *F*	*Main set in coastal and other small craft (associated receiver CR*300/1). *Mains- or battery-operated.*	375-500 *Kc/s.*	*A.*1. *A.*2.	40-50 *w.* 20-25 *w.*	*Master oscillator.*
		1·2-8·3 *Mc/s.*	*A.*1. *A.*2. *A.*3.	40-50 *w.* 20-25 *w.* 12-15 *w.*	*Master oscillator or crystal.*
608	*Main set in coastal and other small craft.*	375-500 *Kc/s.*	*A.*1. *A.*2.	40-50 *w.* 20-25 *w.*	*Master oscillator.*
608 *E* 608 *F*	607 + *additional transmitter* 8-20 *Mc/s. Mains- and battery-operated.*	1.2-8·3 *M/cs.*	*A.*1 *A.*2. *A.*3.	40-50 *w.* 20-25 *w.* 12-15 *w.*	*Master oscillator or crystal.*
		8·0-20·0 *Mc/s.*	*A.*1. *A.*2. *A.*3.	40-50 *w.* 20-25 *w.* 12-15 *w.*	
American TBL	*Main set in destroyers and certain other vessels.*	175-600 *Kc/s.*	*A.*1. *A.*2.	200 *w.*	*Master oscillator (temperature-controlled).*
		2-18·1 *Mc/s.*	*A.*1.	100 *w.*	
		175-600 *Kc/s.*	*A.*1.		
		2-18·1 *Mc/s.*			
American TCE	*General purpose. Low-power set.*	350-9,050 *Kc/s.*	*A.*1. *A.*2. *A.*3.	100 *w.* 100 *w.* 35 *w.*	*Self-excited.*
American TDE	*General purpose. Low-power set.*	300-18,100 *Kc/s.*	*A.*1. *A.*2. *A.*3.	100 *w.* 30 *w.* 25 *w.*	*Master oscillator.*

H/F TRANSMITTERS.

Type	*Where fitted*	*Frequency range*	*Wave form*	*Power to aerial*	*Type of drive*
57*CH/CMR* and 57*DM/DMR*	*Main and second offices of cruisers and above.*	3-20 *Mc/s.*	*A.*1. *A.*2. *A.*3.	500-3,000 *w.*	*Master oscillator or P.C.C.*
89 *M* 89 *P*	*Aircraft direction set in cruisers and above.*	1·5-200 *Mc/s.*	*A.*1. *A.*3.	350-250 *w.*	*Crystal or Master oscillator.*
89 *Q*	*Main set in certain escort vessels.*				
American TBK	*Main H/F transmitter in Fleet destroyers and certain other vessels.*	2-18·1 *Mc/s.* 2-9·05 *Mc/s.*	*A.*1. *A.*1.	500 *w.* 75 *w.*	*Master oscillator (temp.-controlled).*
American TBM	*Main H/F transmitter in Fleet destroyers and certain other vessels.*	2-18·1 *Mc/s.* 2-9·05 *Mc/s.*	*A.*1. *A.*2. *A.*3. *A.*1.	500 *w.* 350 *w.* 350 *w.* 75 *w.*	*Master oscillator (temp.-controlled).*
	N.B.—The modulator is not normally fitted in destroyers, hence R/T and M.C.W. facilities are not available.				
American TCK	*Main H/F set in light craft.*	2-18·1 *Mc/s.*	*A.*1. *A.*3.	400 *w.* 200 *w.*	*Master oscillator temp.-controlled.*
American TCS	*General purpose. Low-power inter-comm. set with associated receiver.*	1·5-12·0 *Mc/s.*	*A.*1. *A.*3.	25 *w.* 10 *w.*	*Master oscillator or crystal. The receiver can also be crystal-controlled.* (*F*-455)

VH F TRANSMITTERS

Type	*Where fitted*	*Frequency range*	*Wave form*	*Power to aerial*	*Type of drive*
86*M* *Low power VH F Transreceiver.*	*Ship to air communication set in corvettes and above.*	100-156 *Mc s*	*A.*3	6-8 *watts*	*Crystal control with trans. and receive.*
87*M* *associated receiver P*104.	*Ship to air inter comm. set in corvettes and above.*	100-156 *Mc s.*	*A.*2. *A.*3.	40-50 *w.*	*Crystal.*
American TBS *Low power VH F trans-receiver*	*Ship-ship inter-comm. set in corvettes and above*	60-80 *Mc s.*	*A.*2. *A.*3.	30-50 *w.*	*Crystal control both trans. and receiver.*

L/F, H/F, M/F RECEIVERS

Type	*Service*	*Frequency Range*	*Remarks*
*A*50 *M*50	*General purpose L/F, M/F*	15-550 *Kc/s.*	

B50	*General purpose M/F, H/F*	550 *Kc/s.*-23 *Mc/s.*	
B28	*General purpose L/F, M/F, H/F*	60 *Kc/s.*-30 *Mc/s.*	
B29	*General purpose L/F, M/F*	15 *Kc/s.*-550 *Kc/s.*	
AR88	*General purpose L/F, M/F, H/F*	75 *Kc/s.*-550 *Kc/s. and* 1.5 *Mc/s.*-31 *Mc/s.*	*Canadian manufacture and can be in lieu of B28 although not mechanically inter-changeable.*

In addition there are small numbers of American receivers covering the L/F, M/F and H/F ranges fitted in ships.

VH/F RECEIVERS

*P*104	*VH/F receiver for use with Type* 87*M.*	100-150 *Mc/s.*	*Crystal control.*

Details of the equipment for M/F and H/F communication circuits now coming into service are given in Table 3. The H/F transmitters have been designed :—

(a) *To have good frequency accuracy and stability.*

(b) *To give good R/T quality.*

(c) *To match into the wide range of aerials and trunks with which they may be used with the maximum efficiency obtainable.*

The Type 601/5 transmitters consist of a range of M/F and H/F transmitters of low and medium power built on the unit principle in order to facilitate maintenance and by using common units to simplify and ease the problem of instruction and reduce the quantity of spares which have to be carried.

The receivers B40 and B41 have been designed to give accurate frequency setting and good frequency stability. They have sufficient R/F selectivity and incorporate limiter devices to reduce interference and the radiation has been reduced to the minimum.

Type 612, with the associated receivers B46 and B47, has been designed as a transportable set, and will also be used as the main set for coastal craft and as an emergency set.

Equipment designed for aircraft must be small and as light as possible. It must be reliable and simple to operate, and equipment common with the R.A.F. is used. Similarly the equipment at R.N.A. stations is largely common with R.A.F. ground station equipment.

TABLE 3

DETAILS OF EQUIPMENT NOW COMING INTO SERVICE

A. Transmitters Type 601-605.

Type No.	*Description and Frequency range*	*Wave-Form*	*Power Supply and lead*	*Size*	*Replaces*
601	50 *watts, H/F* 1·5 *to* 24 *Mc/s.*	*CW* *MCW* *R/T*	230 *volts* 50 *cycles* 600 *V.A.*	*One rack* 3′8″ *high* 29½″ *wide* 15″ *deep*	*Types* 60 *F* 60 *D* (*H/F only*)
602*E*	50 *watts H/F M/F with emergency battery operation* 200-500 *Kc/s.* 1·5-24 *Mc/s.*	*CW* *MCW* *R/T* *CW* *ICW*	230 *volts* 50 *cycles* 600 *V.A.* 24 *volts battery*	*One rack* 5′6″ *high* 29½″ *wide* 15″ *deep*	*Type* 60*E, etc.*
603	400 *watts H/F* 1·5 *to* 24 *Mc/s.*	*CW* *MCW* *R/T*	230 *volts* 50 *cycles* 4 *K.V.A.*	*Two racks, each*) 6′ *high* 29½″ *wide* 23″ *deep*	*Type* 89 *TBK* *TBM*

Type No.	*Description and Frequency range*	*Wave-Form*	*Power Supply and lead*	*Size*	*Replaces*
604	400 *watts M/F* 200 *to* 500 *Kc/s.*	*CW* *MCW*	230 *volts* 50 *cycles* 4 *K.V.A.*	*Two racks, each :* 6′ *high* $29\frac{1}{2}''$ *wide* 23″ *deep*	*TAJ*
605	400 *watts H/F M/F* 200 *to* 500 *Kc/s.* 1·5 *to* 24 *Mc/s.*	*CW* *MCW* *R/T*	230 *volts* 50 *cycles* 4 *K.V.A.*	*Three racks, each :* 6′ *high* $29\frac{1}{2}''$ *wide* 23″ *deep*	*Type* 49 *TBL* *TAJ/TBK*

*B. Receivers B*40 *and B*41.

Type	*Service*	*Frequency Range*	*Remarks*
*B*40	*General purpose M/F-H/F*	640 *Kc/s.*-30 *Mc/s.*	*Scale directly calibrated in frequency with built in crystal calibrator*
*B*41	*General purpose L/F-M/F*	15 *Kc/s.*-640 *Kc/s.*	*Scale directly calibrated in frequency with built in crystal calibrator*

C. TRANSPORTABLE AND EMERGENCY EQUIPMENT TYPE 612

Transmitter

Frequency Range	*Wave form*	*Power to aerial*	*Drive*
1·5-13·0 *Mc/s.*	*A.*1. *A.*2. *A.*3.	24-40 *watts* 12-20 *watts* 12-20 *watts*	*Master oscillator temp. controlled calibrated direct in frequency or crystal.*

Receivers

Type	*Frequency Range*	*Remarks*
*B.*46	1·4-15·0 *Mc/s.*	*Direct reading frequency scale with built in crystal calibrator. Can be crystal controlled.*
*B.*47	15·0-27·0 *Kc/s.* 40·0-500 *Kc/s.*	*Direct reading frequency scale.*

To complete the picture mention must be made of the equipment, both portable and transportable, which has been introduced for special purposes, for example, landing operations. In general the equipment differs from ship-borne equipment only in matters of detail ; the equipment must be small and robust and have a self-contained power supply. For the Normandy landings a very comprehensive Cross-Channel communication system using VH/F (85-95 Mc/s.) was used. The system was designed to work into teleprinter and telephone land-line networks, and messages could be routed from Point A to Point B using land lines and VH/F radio links.

Control circuits, power supplies and the positioning of offices in the ship have not been discussed, as they are not considered to come within the scope of this article, but it must be realised that all these contribute to the overall efficiency of communications.

It is hoped that this article has given a sufficiently broad picture of Naval radio communications to show the vastness of the system and to focus attention on some of the salient problems. The rate of growth of radio communications during the war years has been phenomenal and in the next few years the lessons learnt during war and the technical advances made must be incorporated in the communication systems and in the equipment.