

TELECOMMUNICATIONS IN WAR

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In presenting this Address to the Radiocommunication Convention, I would first indicate that, as the title implies, its scope includes some references to line communication. The two means of communication are so closely linked that I think the subject cannot be adequately dealt with unless radio and line communication are considered to be in many respects complementary.

Modern war calls for a rapid and reliable communication system, and this can be achieved only by the properly co-ordinated use of both line and radio systems; each must play its part, and their relative merits must be exploited fully to provide the final complex network necessary for the effective mobilization of the war potential. Such a communication network must embrace the home and operational fronts and provide for the effective transmission of intelligence, in the form of speech or code signals, on a world-wide basis. The maintenance of an adequate broadcasting service for the home, allied and enemy-occupied countries is vital to the maintenance of morale, while propaganda services to enemy countries play an important part. In considering the evolution of our communication system it must be realized that the art of waging war underwent great changes in the period 1914 to 1939, and, in addition, that major advances were made in both line and radio technique during the interval. As a consequence of these factors, radio, while used with success on a relatively limited scale in the First World War, had to play a much more important and vital part in the Second World War. On the line side, the development of multi-channel carrier systems had revolutionized the design of the land-line network, and such systems were extensively employed to provide the main land-line circuits to the higher formations.

The widespread use of radio presented special problems, which included the necessity for careful planning and the co-ordination of frequency allocations; high-frequency stability to ensure maximum utilization of the available frequency spectrum; detailed forecasting of ionospheric conditions affecting propagation; strict control of the form and degree of intelligence transmitted, because of possible interception and of the radio counter-measures employed by the enemy. In addition to radio telegraph and telephone communication, systems of direction-finding and navigational aids have been developed and greatly improved.

I cannot attempt to cover the whole field of these developments; various phases are covered in the papers to be given at this Convention, and I will confine myself to some general aspects.

EXTENT OF LINE COMMUNICATION REQUIRED IN THE UNITED KINGDOM

Following the invasion of Czechoslovakia, preliminary plans were prepared by the Post Office so that the necessary line communications would be available for the defence of this country as soon as required. One of the first essentials was a review of the existing arrangements for the provision of emergency circuits. An emergency circuit consists primarily of a switchable portion, normally in use for the public system, which can be connected quickly to two local ends, thereby forming a complete circuit between the new terminals.

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By August, 1939, arrangements were in hand for some 500 long-distance emergency circuits and for a much greater number having a radius of under 25 miles. During the latter part of that month requests were received from the Services for switching into service certain of these circuits for mobilization purposes and operational requirements.

After the declaration of war, the Services asked for more emergency circuits to be switched in, for others to be arranged and for new private circuits to be provided. It was soon realized that the majority of the emergency circuits which had been handed over would be required for some years, and many of them were therefore converted into permanent private wires. The peak of the private-wire network, approaching 10 000, was reached in August, 1944, during the flying-bomb attacks on London. The average length of these circuits was 75 miles, and as telephone circuits of this length must operate on a 4-wire basis, the equivalent length of single conductor used was approximately three million miles. At the same period the number of private telephone circuits under 25 miles radial was about 50 000. The total equivalent of single conductor used in the defence of this country and the assault on the Continent can be taken as four million miles.

This extensive line network provided for both a telephone service and a teleprinter network using voice-frequency channels. The initiative for providing this service came from the R.A.F., and of all the departments served by it they were the largest. The main signals centres for this network dealt with an ever-increasing amount of traffic as the war progressed. In the quarter including D-day well over one million messages were dealt with by this system, and at the peak of the war effort the switching centres were handling a total of approximately 30 000 calls a day.

I have indicated the magnitude of the problem. You will appreciate that the expansion of the trunk network of this country to meet these extensive requirements was a major undertaking.

SAFEGUARDING OF LINE COMMUNICATION

Immediately following the occupation of France by the enemy, a scheme was devised to provide telegraph communication by radio between important centres throughout the country as a precaution against the possibility of complete isolation of part or parts of the country due to bombing, invasion, sabotage or other cause. In particular, this reserve was to be available at the headquarters of the twelve Regional Commissioners. By the end of July, 1940, emergency stations had been established at all the Regional Commissioners' Centres and a number of other towns. A total of 32 such stations were set up, and facilities were provided at nine of the coast stations for co-operation in this scheme. A number of frequencies in the marine mobile frequency band were allocated for the service, and in addition some of the stations were provided with equipments for high-frequency working. In general, the power of the stations did not exceed 0.5 kW, and usually was limited to 0.2 kW or even lower. In addition to these fixed stations, mobile installations in vans equipped with facilities for short-wave wireless-telegraph

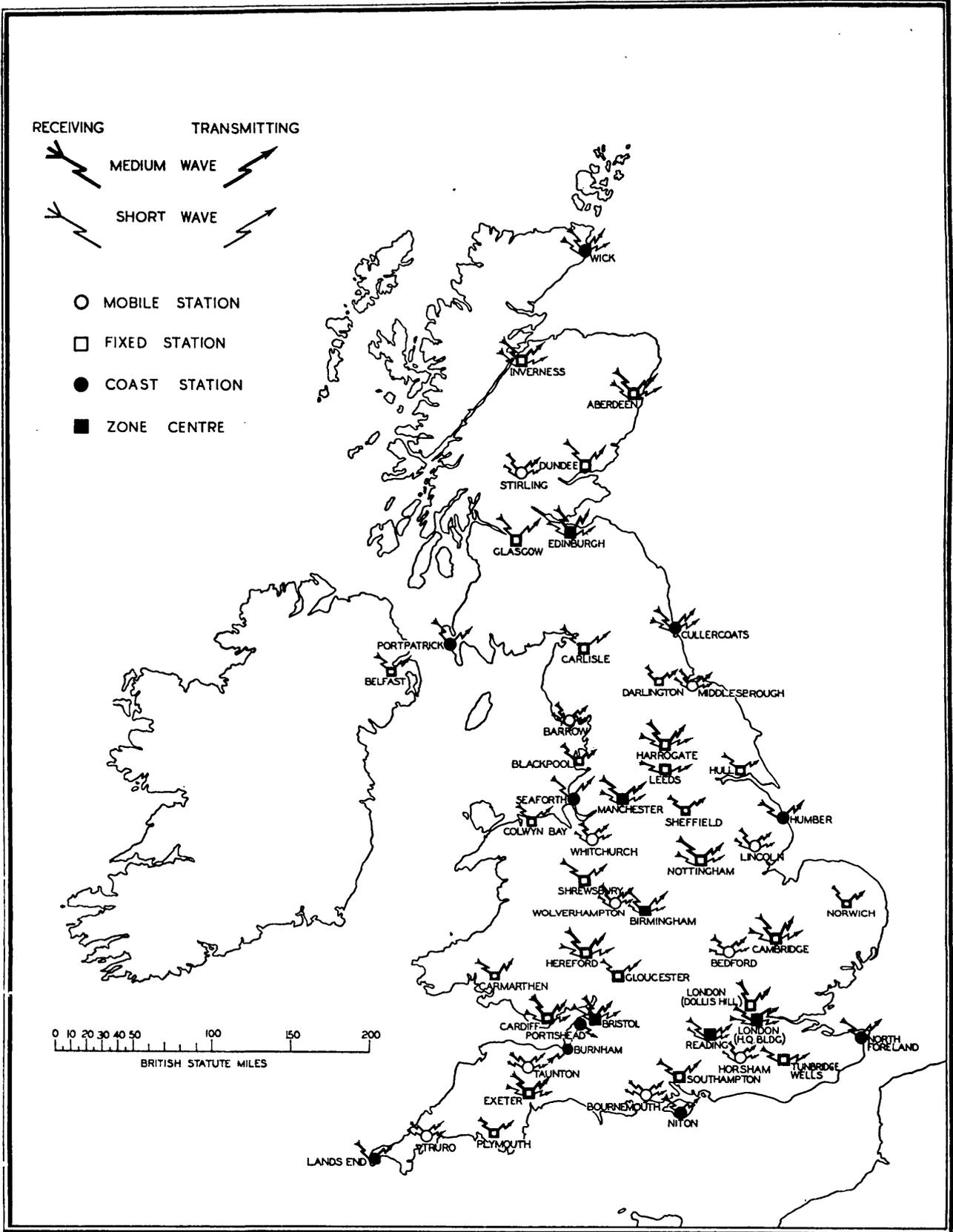


Fig. 1.—Inland emergency wireless stations.

working were provided at eleven centres distributed throughout the country; also six mobile v.h.f. radiotelephone links, each capable of connection to any subscriber's line in the telephone network. The scope of the scheme is shown in Fig. 1. By early 1944, mobile equipments were provided whereby, in an emergency, multi-channel v.h.f. radiotelephone links cross-connecting selected repeater stations on different cable routes radiating from London could be quickly established and thus enable up to two groups of twelve circuits to be diverted to alternative routes. The scheme was known as the "London Ring Main."

CERTAIN CONTROL MEASURES

Early in the war, it was decided that a check and record must be made of all transactions involving wireless transmitters and certain components, notably valves. Originally, permits were required for each transaction, but later a "continuing" permit was issued to approved firms. The number of permits issued was 320 025.

As a result of concern expressed by the Fighting Services, especially the Air Ministry, regarding uncontrolled radiation which might interfere with Service radiocommunication, or possibly serve as a radio beacon or be used for unauthorized radio transmissions, apparatus with an output of 10 watts or more at a frequency over 10 kc/s was brought under control. This involved the impounding of apparatus, advising on methods of obviating disturbances and tests of equipment for efficient screening. The number of permits issued was about 2 000, and the number of persons whose apparatus was impounded was about 1 400.

At the outbreak of the war all licensed amateur transmitters (over 8 000 in number) were closed down, and essential parts of the equipments impounded. Also over 3 000 persons known to have been interested, but who had not been licensed, were circularized, and apparatus was impounded in 270 cases. Thereafter full co-operation with the Services and Security Authorities in connection with illicit transmissions and the issue of experimental licences was maintained.

UTILIZATION OF COAST STATION SERVICES

The ordinary commercial wireless communications to and from ships were prohibited at the outbreak of war, the Admiralty assuming responsibility for the wireless communications of the Merchant Navy in addition to those of the Royal Navy. For this purpose use was made of the Post Office organization, the closest contact being maintained between the wireless branches of the two Departments. In peace time the Post Office stations dealt with all ship-shore traffic, the most important being that with ships in distress. In war, Admiralty instructions made ships keep wireless silence, except for sending vital messages, thereby avoiding the risk of disclosing their positions to enemy submarines and raiders, and to enemy shore stations equipped with direction-finding apparatus.

On the other hand, a mass of messages had to be sent from the Admiralty through the coast stations to ships, mostly in code by radiotelegraphy, but sometimes by radiotelephony in the case of small ships not fitted with telegraph apparatus. The most vital communications were, of course, those with ships attacked by the enemy, and it was here that the long experience of staff accustomed to dealing with commercial ship communications bore full fruit. In 1940, and again in 1941, the coast stations handled some 1 100 distress and urgency cases as against 202 in 1938; each station had direct telephone contact with the appropriate naval authority so that no time was lost in passing on the distress messages for action. The Admiralty also made use of the stations for communication with ships of the Royal Navy; for

example, one of the stations assisted in the communications which sealed the fate of the *Scharnhorst*.

The stations were also used on behalf of the Air Ministry in the air-sea rescue organization for communication with aircraft in distress and rescue surface craft, and one of the stations was used throughout the war for communication with civil aircraft. Moored rescue craft were established at strategic points in the North Sea for which aircraft could make when in danger of coming down in the sea. These carried radio apparatus for calling assistance. Automatic battery-operated transmitters were supplied in large numbers for use in ships' lifeboats—the Post Office organizing the production of some 4 000 sets—while another development of small automatic transmitters working on 500 kc/s using hand generators proved of great value to airmen. For instance, on one occasion an aircraft dinghy near the Heligoland Bight was heard by several British coast stations, radio bearings enabling its position to be determined to within about three miles and the R.A.F. to effect a rescue.

Full use was made of the direction-finding facilities at the coast stations, and three extra stations used solely for informing ships of their bearing relative to the station were erected and worked by the Post Office for the Admiralty at the north-west approaches to Scotland. Three additional coast stations were also erected by request of the Admiralty, bringing the total number of coast stations to eighteen. Two mobile stations, each completely self-contained with power unit and land-line equipment, were also constructed and held ready for use in the event of damage to any of the normal coast stations. Fig. 2 shows the final distribution of all coast stations.

LONG-DISTANCE SHIP-SHORE SERVICE

The changes brought about by the war in the long-distance telegraph service to ships have been mainly in methods of operation, and changes in equipment have been largely incidental to these operating changes. Before the war, traffic to ships originating in this country, or from ships for delivery in this country, was handled by the twin radio stations at Burnham and Portishead in Somerset; Burnham is the receiving station, the transmitters being situated at Portishead and operated by remote control from Burnham. Messages for ships handed in at post offices were sent to Burnham and at scheduled times a "traffic list" was transmitted. This traffic list consisted of the call signs of all ships for which messages were on hand. A ship's operator, hearing his call sign in the traffic list, would call Burnham, and, contact having been established, the message would be passed on to the ship. Messages from the ship to Burnham were dealt with similarly.

With the outbreak of war, Burnham and Portishead, as well as the coast stations, were taken over by the Admiralty. The Post Office continued to staff and manage the stations, but operationally they became Admiralty stations. A small number of naval telegraphists were stationed at Burnham to augment the Post Office staff. It was important that ships at sea should not disclose their positions to the enemy, so that all radio signalling by ships had to be reduced to a minimum. The world was divided into areas, in each of which was situated an area transmitting and receiving station (in some cases the receiving stations were duplicated). Messages for ships were broadcast from the appropriate area stations at scheduled times, but no acknowledgment of receipt was given by the ships. A network of point-to-point communication channels was set up between the area stations, so that messages originating anywhere in the world could be routed to the appropriate area stations.

In some cases, it was essential for ships to send messages to shore, and in order to avoid repetitions by the ship (increasing the risk of betraying the ship's position to the enemy) duplicate

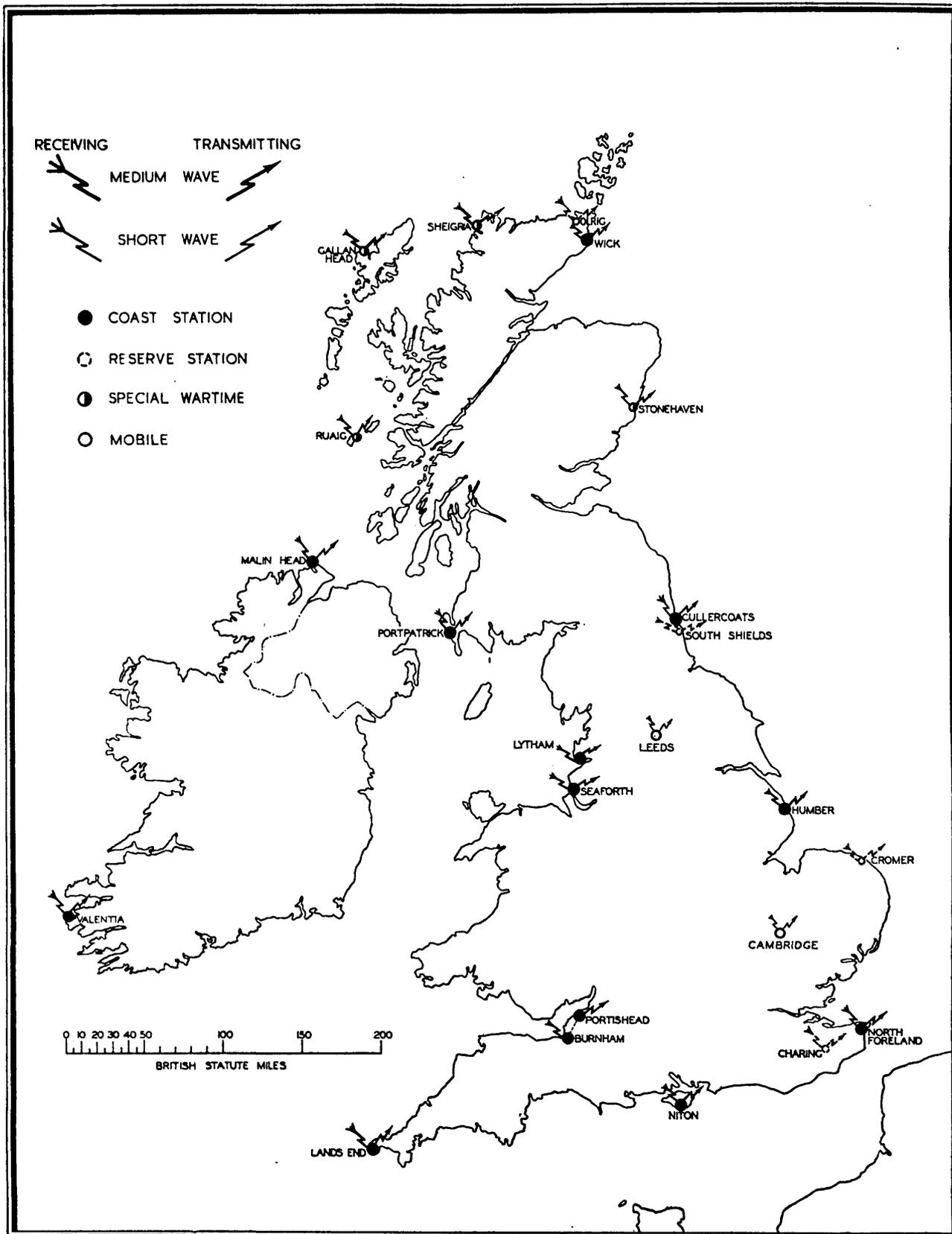


Fig. 2.—Coast stations.

receiving stations were set up in some areas. In this country, such a station was established in the West Midlands. This was equipped with a set of directional aerials for receiving from all quarters of the globe. The operators were in touch, by means of loudspeaking telephones, with their colleagues at Burnham. It was often found that in conditions of fading or interference parts of a message missed at one station would be received clearly at the other, and the ship was not required to repeat the message.

The number of radio officers carried in merchant ships was nearly trebled to ensure a continuous operator watch at sea. The expansion is shown by the fact that, whereas in 1938 the number of certificates of proficiency in radio operating issued by the Post Office totalled 531, during the war an average of 2 500 a year were issued.

At the end of the war it was decided to retain the broadcast method of passing traffic to British ships and to ships of such foreign countries as wished to take part in the scheme. Traffic for other ships is handled by pre-war methods. A message for a British ship, handed in at a post office in this country, is sent by teleprinter to Burnham, where a Ships Bureau is maintained. Records of the position and course of all ships are kept at the Bureau (see Fig. 3). The message is sent on over point-to-point

and had also to be combined with lightness and extreme compactness. Mechanically, the infantry type of set had to withstand the conditions of front-line battle in all weathers, while the tank set had to be immune from the very severe shocks of tank movement; electrically, these sets had to be extremely simple, while capable of operation on nets of up to 40 or 50 stations on one frequency and with an instantaneous "flick" change to other frequencies. Similar advances were made throughout the field of longer-range sets used by Royal Signals, of which the largest station in regular use was the mobile 5-kW Golden Arrow, used to connect major headquarters overseas with this country. These stringent requirements were met with reasonable success without any startling innovation in technique, development being the result of steadily improving circuit components rather than of fundamentally new principles. The whole range of these sets used the h.f. band, amplitude modulation was universally employed, and telegraph transmission was by the morse code, high-speed morse being used with the largest stations. There were certain sets outside the h.f. band, such as the No. 26, a multi-channel set in the v.h.f. band, based on the type of equipment adopted for use with the trunk network in this country, and used to provide the first cross-Channel telephone communication; and the Nos. 17 and 36 Sets used in anti-aircraft com-

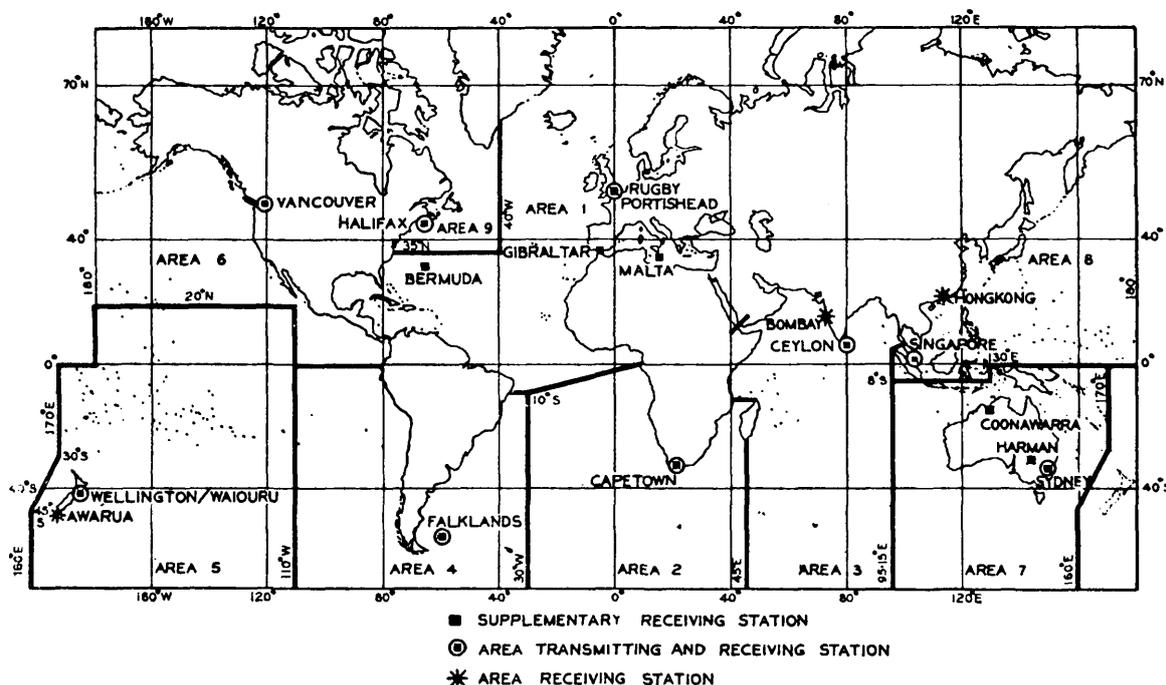


Fig. 3.—Areas for long-distance ship-shore radiocommunication.

channels to the appropriate area station. Ships notify Burnham Radio when they enter or leave port and when they go from one area to the next, so that the records in the Ships Bureau may be kept up to date. This long-distance ship service, evolved as a war requirement and now expanded, is proving most efficient for normal ship-shore communication.

SOME FEATURES OF MILITARY COMMUNICATION

Radiocommunication for military use was very widely extended during the war, mainly in the smaller types of set. Infantry units were equipped with pack sets powered by dry batteries; tank formations relied for their control in battle on their wireless-telephone communication. The requirements of these classes of set were very stringent, both mechanically and electrically,

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munications in this country, but these were restricted to special applications. Some figures of radio set production may be of interest. The total numbers of sets employing transmitters made for the British Army was over 600 000. The number of sets on the normal establishment of an infantry division rose from 74 before the war to over 900 at the close of the campaign. It will be readily appreciated that the frequency congestion in the limited h.f. band was a continuously growing problem, other users besides the British Army making similar increased use of this band.

There was one type of field set produced in time for the landing in France in 1944 which used entirely novel techniques and which deserves special mention. This was the No. 10 Set, which,

employing a wavelength of about 6 cm, obtained by the use of magnetrons, using waveguide feed to aerials with parabolic reflectors on high steel towers, and making use of timed pulse modulation giving eight speech channels, exemplifies a very rapid introduction of modern techniques into military field wireless equipment. A chain of No. 10 Set stations was used by Field-Marshal Montgomery to communicate from the east bank of the Rhine, and also, of course, on many less-famous occasions.

The introduction of v.h.f. radio for aircraft working marked a great advance in air communication. By 1940, Fighter Command had decided to abandon h.f. communication between aircraft and between aircraft and ground, and set up an extensive v.h.f. radiotelephone system. This was in operation throughout the Battle of Britain, and it is claimed that this vastly improved system was one of the contributing factors in enabling Fighter Command to meet and defeat the vastly numerically superior forces of the Luftwaffe.

In this brief résumé of military radio in the war, it is appropriate to record the achievement of those responsible for training. In civilian life the number of people with any knowledge of the operation of wireless transmitters is very few, familiarity with the morse code is nowadays unusual, and even a simple practical knowledge of electrical fundamentals is by no means universal. The successful employment of this enormous quantity of military radio equipment reflects very favourably on the effort put into training of very large numbers of personnel up to the standard of efficiency that was attained, and, as I feel that this tends sometimes to be overlooked, an appreciation is due to those responsible for this essential branch of the work.

MONITORING AND INTERCEPTION SERVICES

It will be appreciated that during the war both sides expended a great deal of effort in the interception of enemy radiocommunications, and, as a consequence, there was a rapid development in the techniques involved. Monitoring of wireless transmissions is also a necessary peace-time function for keeping watch on interfering transmissions and on persons offending against national regulations. An efficient organization for direction-finding is a necessary part of any such service, and the number of papers presented at this Convention is an indication of the interest displayed in this connection. The fundamental difference between an interception station and a normal receiving station, designed to receive a scheduled service of some form or other, is that, whereas in the latter case both ends of the service are under the designer's control, in the former the transmitting station is, to say the least, non-co-operative. In many cases special precautions are likely to have been taken at the sending end to reduce the risk of interception, namely by choice of frequency and use of directional aerials, and the received field strength at the interception station may be expected to be generally lower than that received by the proper user. Thus the interception station often has to be capable of receiving transmissions from any direction and over a wide band of frequencies.

In one such interception station, some 45 miles of coaxial cable, of which only some seven miles were external to the building, was used for interconnection, together with well over 5 000 coaxial jacks and a corresponding number of plugs with some 2 000 yd of coaxial patching cords. In addition, over 28 miles of low-frequency cabling was used, much of which contained four or more pairs; over 12 000 terminations were involved in the low-frequency work alone.

THE NEED FOR BROADCASTING

The broadcasting of news and entertainment is a development of radiocommunication which, because of its direct impact on

the general public, has assumed great importance in peace and in war. Domestic broadcasting has become so closely woven into the fabric of everyday life that it may indeed be regarded as an essential service. In war it assumes greater importance than in peace time, not only for the dissemination of news and entertainment, but as a medium through which national leaders may address the whole of the nation, and it provides a means of instructing and controlling sections of the population in sudden emergencies—a facility which, happily, has not been much needed in this country.

Broadcasting is not confined to the domestic sphere alone. It has been used, and will no doubt continue to be used, to attract audiences in foreign countries and to place before them news and views of which they might otherwise remain in ignorance. Its value in maintaining and strengthening the ties between Great Britain and the other parts of the Commonwealth needs no emphasis. These factors render overseas broadcasting of greater importance in war time. This was particularly true during the recent war, when practically the whole of Europe was occupied by Germany and her satellites.

Although broadcasting, as generally understood, had no counterpart in the War of 1914–1918, September, 1939, found the British Broadcasting Corporation well prepared to maintain domestic broadcasting in all circumstances and to expand its overseas services. The necessity for guarding against the use of broadcasting stations as beacons by enemy aircraft involved changing over immediately to single programme for the whole country, radiated by a number of very accurately synchronized stations. The magnitude of this task should not be underrated. As time went on a large number of low-power transmitters were added to this system of common-wave stations in order to improve reception in various populous areas. The experience gained has already been used since the war to extend the areas in which the Third Programme can be received.

The importance of disseminating accurate news in foreign countries and in combating Axis propaganda led to a great increase in broadcasting to Europe and further afield. During the course of the war the most powerful broadcasting transmitter in the world was erected at Ottringham for medium- and long-wave transmission to Occupied Europe, and the largest short-wave broadcasting station in the world was built in Cumberland.

In common with other large organizations the British Broadcasting Corporation was involved in all the difficulties that accompany the evacuation of large sections of staff to various parts of the country and the formulation of plans to meet various possible emergencies. Not the least important of its activities was the setting up of an organization for monitoring broadcasting stations in Europe and certain other parts of the world.

A less familiar aspect of broadcasting, but one of the greatest importance to the Press and the general public abroad, is the dissemination of news by radiotelegraphy. The Post Office is responsible for the transmission of all broadcast and multiple-destination news sent from this country to all parts of the world by radiotelegraphy. For many years before the war these news services were conducted on behalf of the Foreign Office, Reuters and the Shippress News Agency, which provided news for ships at sea. As might be expected, the war had the same effect on this form of broadcasting as it did on the more familiar overseas broadcasting activities of the B.B.C. In 1938 the Post Office handled an average of 350 000 words a month on these services. In 1943, however, the figure had increased to nearly five million words a month, and it is now over seven million.

Before the war, broadcasts to the more distant parts of the world, as for those to Europe, were carried out using omnidirectional transmissions, but from 1941 onwards extensive use

was made of broad-beam transmissions for continents other than Europe and many more transmitters were provided.

Reuters use the Hellschreiber system of transmission for many of their recipients. Prior to the war all Hellschreiber equipment came from Germany, and, when this source of supply failed, arrangements were made to design and obtain substitute equipment for all new subscribers from within this country. Much of this war-time expansion has now its application for an ever-expanding service of broadcasting by telephony and telegraphy.

THE INTRODUCTION OF NEW TECHNIQUES

Perhaps one of the most important war-time developments in long-distance point-to-point radiotelegraph technique is the operation of multi-channel voice-frequency telegraph channels on single-sideband radiotelephone equipment. Although practically all the British overseas telephony services were shut down during the war, there was a great increase in the volume of radiotelegraph traffic. When invasion threatened and there was a possibility of submarine cables being cut, the Post Office with the co-operation of the American Telephone and Telegraph Co., developed the technique of operating a number of morse or teleprinter channels on each of the single-sideband radio-telephone channels. This system, which made use of radio-telephone equipment, was very successful, and the flexibility that it affords appears to have great potentialities for civil as well as military communications. It has been standardized for long-distance point-to-point links by the Army and R.A.F., and the Royal Navy contemplate adopting it. The R.A.F. were first to realize the flexibility which could be attained by the use of 6-channel v.f. with teleprinter working on overseas radio links, and extensively adopted it before the end of the war in place of high-speed automatic morse transmission. In addition to its use for multi-channel telegraph operation, the single-sideband system is being adopted for all long-distance overseas telephone links.

Very high frequencies have been exploited during the war for short-distance point-to-point links, and more widely for short-distance communication with and between mobile units of all kinds. It still forms the backbone of radiotelephone communications associated with aircraft and all types of fighting vehicle, and was widely used in naval craft. Multi-channel telephone links have been developed by associating coaxial-cable terminal equipment with wide-band v.h.f. radio transmitters and receivers. Use was made of such links by the Army during the war and by the Post Office, who introduced highly developed systems of this type as an integral part of the telephone and telegraph network.

Perhaps the most outstanding development in radiocommunication and radar technique has been the exploitation on a large scale of frequencies far higher than those used before the war. In this respect Great Britain has led the world. As is well known, frequencies of the order of 3 000 Mc/s were first used on a large scale in British radar equipment. Shortly afterwards, however, the Ministry of Supply evolved a 5 000 Mc/s 8-channel pulse-modulated radiotelephone set for Army communications. This equipment, which was widely used, demonstrated that a combination of time-division multiplex and microwave technique could be used with advantage in providing simple easily-erected multi-channel radiotelephone links, and was the forerunner of a number of other systems that have been developed at home and abroad.

SUPPLY OF TELECOMMUNICATION EQUIPMENT

To assist in the production and distribution of radio and allied types of communication equipment, a number of Inter-Service Committees were established. The radio committees were sponsored by the Ministry of Aircraft Production, and those

dealing with line-communication equipment and cable by the Post Office. These committees were charged with:

- (a) Collating the requirements of all users, both home and overseas.
- (b) Augmenting productive capacity to meet essential requirements.
- (c) Standardizing equipment and components.
- (d) Arranging the order of production of conflicting demands.

Regular meetings were held with manufacturers at which the forward loading was reviewed and plans were made for changes in production rates or for the introduction of new items. Information was exchanged between the radio and line telecommunication equipment committees regarding the forward loading on the principal manufacturers. At these meetings current production rates were also compared with the planned targets, and causes of any "short falls" were examined. Continuous assistance was given to the purchasing sections of the principal manufacturers regarding the supply of raw material and component parts. This necessitated vigorous progressing action and co-operation with various material and component controls.

Throughout the war, the shortage of man-power was the dominant factor limiting production, and constant effort to obtain additional labour and to compensate for wastage was necessary. Part-time workers were recruited to the maximum possible extent to make good the shortage of full-time workers, and outworking schemes, whereby housewives with only limited amounts of spare time took work home or worked a few hours a week in a village hall, were instituted in many areas. In view of the operational importance of communication equipment, the production of much of it was covered by "preferences in the allocation of labour" and by deferment of call-up of many key workers.

The radio and line telecommunication equipment production committees inevitably competed for the same manufacturing capacity, and close co-operation was essential to co-ordinate conflicting demands. In the early days of the war the need for radio equipment rose rapidly, whereas the demand for telephone exchange equipment declined. Radio orders were therefore given to the telephone equipment manufacturers. After Dunkirk, demands for line transmission equipment became an equal priority with radio, and, later, large requirements of telephone and telegraph instruments and switchboards added to the load. Adjustment and, above all, expansion of productive capacity had therefore constantly to be made. This involved equipping new factories and bringing in manufacturers not previously in the communications field. In addition, the question of safeguarding production against enemy air attack had constantly to be kept in mind. All equipments had to be made in at least two locations in different parts of the country, and numerous other safeguards had to be applied.

As a result of all the steps taken, the supplies of telecommunication equipment, except in the early days of the war, were maintained at a level to meet Service requirements.

STANDARDIZATION OF RADIO COMPONENTS

After Dunkirk it was necessary to re-equip completely the British Army with communication equipment. The Battle of Britain had proved the need for more and better radio communications for the Air Force, and the Admiralty were anxious to apply radio on an expanding scale.

By the end of 1940 it was therefore possible to estimate equipment requirements for the next twelve months, and it was immediately evident that a bottleneck would occur in the production of thermionic valves. Requirements, including spares, were estimated at 19 million, against a total production, restricted

by bomb damage, of approximately 10 million. The gap between demand and supply had to be bridged, and for this purpose an Inter-Services Committee was set up, responsible for:

- (a) Allocating available supplies and estimating future requirements.
- (b) Reducing the number of types in use.
- (c) Expanding the use and production of types most generally useful and capable of easy mass-production.
- (d) Restricting the introduction of new types.

The problem was tackled in a most energetic manner and the committee quickly issued lists of "preferred" types, namely types which should be used wherever possible; of "restricted" types, which were more difficult to manufacture and could be used only for special circuits; and of "black list" types, which were very difficult to manufacture and were to be avoided.

Estimates were made of requirements for two and three years ahead of the less popular, but equally important, types, so that substantial quantities could be made from time to time and ineffective effort resulting from short-term runs largely avoided. By these and other means it was possible to increase output by some 50% and at the same time lay a sound foundation for subsequent additional production by shadow factories, so that in 1945 the production of thermionic valves in the United Kingdom was well in excess of 30 million.

As soon as the Inter-Services Valve Committee had straightened out the valve supply position, shortages began to arise in the supply of essential radio components such as resistors, condensers, transformers, switches and magnetic relays. A similar committee, known as the Inter-Services Components Committee (I.S.C.C.) was set up to control the allocation and distribution of available supplies, to estimate forward requirements, and to arrange appropriate manufacturing capacity. The problem was, of course, much more complex than that of the valve control dealing with only five firms, since the I.S.C.C. had to deal with thousands of variations of some types of components manufactured by some 600 firms and represented by three distinct trade organizations. The three trade associations joined forces temporarily, forming a simple representative body empowered to discuss any major problem direct with the I.S.C.C. Departmental machinery was established to schedule components required for all equipments, so that future requirements could be assessed with some degree of accuracy.

Demands continued to amount at a greater rate than the component industry could be expanded, and by 1943 orders for several "bread-and-butter" components, such as resistors, condensers and transformers, were seriously in arrears. When rapid changes in the operational urgency of equipments occurred, the Committee found increasing difficulty in meeting component requirements owing to the non-interchangeability of the many variations, all similar, but just sufficiently different in some important physical or electrical characteristic to debar interchange. To meet this difficulty an Inter-Services Component Technical Committee was made responsible for standardizing and developing all components. The Committee's first task was to prepare "preferred lists" of all the principal types of controlled components. The lists were to include only the minimum number of components approved for use in new work and agreed by the manufacturers as being suitable for bulk production by several firms.

A "preferred list" of resistance values of fixed carbon resistors was issued, limiting the number of permissible values to 255 compared with the 4 000-odd different values then on order, whilst the number of standard transformer lamination sizes was reduced from 560 to 32. Subsequently, standard ranges of can sizes and terminals for fixed condensers, and standard spring sets

and coil assemblies for magnetic relays, were agreed. Standardization of essential physical dimensions of many other components was also introduced.

Immediately the standardization programme was under way it became apparent that Service equipment would have to be capable of withstanding increasingly arduous conditions of climate, transit and field use. A series of target specifications were issued which included many new tests designed to assimilate these new Service requirements. Within a few months a whole series of standardized hermetically sealed components were rolling off the production lines to meet these specifications.

At about this same period it became apparent that very great operational advantages could be gained, particularly for airborne operations, if the weights of equipment could be very substantially reduced. The problems were investigated, and eventually an entirely new range of miniature components was designed and developed, which from the beginning were in accordance with agreed specifications. Most of these components were capable of operating continuously at 100° C and many were hermetically sealed. With the end of hostilities the urgency for development has ceased, but the need for standardization remains, and it is well that many committees in the technical field are still continuing this most essential function.

QUARTZ CRYSTAL PRODUCTION

When it became apparent that the widespread use of crystal control would be necessary for the setting up of the complex signal networks, the Supply Ministries and Service Establishments took active steps to interest a number of commercial organizations in what was then considered the comparatively large-scale production of quartz vibrators. The problem was immense, since up to that time the production of quartz vibrators had been carried out only on a very small scale as a highly specialized laboratory process, and much remained to be accomplished before production of this vital component in the quantities required could be guaranteed. However, the technical and practical information available was mobilized, and the success which met the efforts of the several organizations concerned will be apparent from the fact that an annual production rate of less than 5 000 quartz vibrators for 1937 was stepped up to over 400 000 in 1942, and to well over a million in 1944. In addition to the increase of production, the quality of the product was improved progressively, and it is perhaps worthy of comment that, as a result of this work, high-grade quartz vibrators mounted in all-glass envelopes are now available for peace-time applications.

PRODUCTION OF RADIO TRANSMITTERS

At the end of 1942, as part of a new organization to ensure that the then growing national needs for radio equipment of all kinds should be adequately supplied, a committee was set up to consider questions of priority of wireless telephone and telegraph transmitters having a power of 5 kW and upwards and to prepare and progress production programmes for such transmitters in consultation with the contractors concerned. An important factor in the preparation of such programmes was that production of the transmitters took from 18 months to two years from the placing of orders. The committee prepared and progressed production programmes for the years 1943, 1944, 1945 and 1946. Special attention was given to the development and production of single-sideband equipments, and, since it was essential to ensure parallel development and production of single-sideband transmitting and receiving equipments, the committee agreed a common specification for single-sideband receivers and prepared and progressed production programmes for single-sideband receivers as well as transmitters.

ADVANCE PREPARATION

Whilst it is a great problem to obtain in peace the money and material required for any of the Armed Forces on the outbreak of war, after hostilities have commenced finance does not present such difficulty. Therefore it seems essential that, as far as possible, material requirements in war should be capable of being quickly met from sources used for production in peace; this refers both to components and to complete equipments.

For purely warlike stores, guns, shells, and so on, this is very difficult, but for radio it may not be, provided it is clearly borne in mind, both by the Services and by industry, that the requirements of both must be kept as similar as possible. In radiotelegraphy, for instance, it would be an ideal arrangement if merchant ship and warship equipments were identical. In shore stations, clearly, the problem is similar and the solution should in many ways be easier. In the opening stages of a war, there is always difficulty in the rapid expansion of trained personnel. Here again, if one can ensure that men who are employed on radio in civil life remain on that work when they go into uniform, much is achieved—but still more is this the case if the equipment on which they have been working in peace time is of the same nature as that which they will be called upon to handle in the Services.

One other problem present throughout the war was, At what point should research and development be halted and a standard plan be adopted? If standardization is delayed too long, the equipment may not become available before the war is over. On the other hand, standardization at too early a stage may introduce a handicap if the apparatus becomes inefficient compared with that of the enemy. This problem has also, of course, to be faced continually in peace time.

This has been a brief résumé of what has been done in telecommunications during war; other papers will deal, in greater detail, with radiocommunication in war-time and its influence on peace-time development. Not only is a record of war-time development desirable from the point of view of its application to war-time needs, but fortunately much of the advances in technique and operation which have been realized are of direct application in peace and can well be used in the building of the world-wide telecommunication system of the future.

I need hardly say that the preparation of this review would have been quite impossible without information from many sources. I am very grateful for this help and particularly for the assistance of Mr. Mumford, who has contributed so much to this Address, in addition to preparing his own introductory paper for the Convention.

