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Remote and Semi-Automatic Control of H.F. Transmitting and Receiving Stations

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The factors creating the growing demand for remote control systems are examined, existing methods for conveying remote control commands and reveitive checks are described, together with straightforward receiver and transmitter control schemes. It is shown how the application of 'system' thinking to h.f. requirements yields a combination of semi-automatic and remote controls as being the best present-day solution to the problems of staffing and operational efficiency.

1 INTRODUCTION

IN THESE DAYS of intense demand for skilled personnel, the geographical location of transmitting and receiving stations often places the h.f. system operator at a severe disadvantage.

The provision of an efficient aerial system of predictable performance, calls for large areas of flat, unobstructed land of good conductivity. Receiving and transmitting stations must be separated from each other by many miles to avoid swamping the receivers. In order to reduce interference to television receivers from the transmitting station, man-made noise at the receiving station and the high cost of land, densely populated areas are to be avoided. Once these conditions are met the operator is indeed lucky if there is a nearby source of skilled personnel.

Staff who are happy to be away from the attractions of large towns, to work shifts and to give up weekends and public holidays are increasingly difficult to find. To attract suitable people the employer is forced to offer expensive inducements such as free transport and assistance with accommodation, so that manned remote sites are not only expensive to maintain but also impose heavy administrative burdens.

Over the years, owing to greater efficiency, there has been a steady decrease in the number of staff required to run transmitting and receiving stations. Much of this increased efficiency has been due to the steady rise in the number of automatic functions incorporated in the equipment.[1] With the introduction of self-tuning transmitters and receivers, an advanced degree of unit automation has been reached, but further advances must now be in the application of automatic functions to overall systems.

Electronic equipment is generally manufactured to withstand environmental conditions the extremes of which no human could tolerate for long. Transmitting and receiving stations, unattended but remotely controlled, lead to substantial savings in the cost of buildings which can be of simplified design, without windows and with the minimum of heating and air conditioning.

The whole success of a remotely controlled system hinges on equipment reliability. The use of semiconductors, in particular silicon power rectifier diodes, together with the extreme simplicity of modern high power r.f. circuitry, has brought reliability well within the desired limits.[2,3,4]

Another advantage of automatic systems is that outage time is reduced by their ability to replace faulty equipment more rapidly and reliably than the watchkeeper.

2 SYSTEMS

In this context 'system' is taken to describe the technique that is adopted to transmit the unique control and indication 'messages' between a central control office and a remotely sited outstation or outstations. In the example under review these outstations consist of either or both h.f. transmitting and receiving stations controlled from a central point such as the Central Telegraph Office.

To exercise control over a remote transmitting or receiving installation, it is necessary to generate a number of individual command signals and to transmit them over a suitable circuit from the control office to the outstation. In a similar manner it is necessary to relay back from the outstation to the control office, sufficient indication information to create at all times a comprehensive display of the state of the controlled apparatus.

Essentially a remote control system consists of:

(a) A controller's position, where command and indication panels are provided to enable the watchkeeper to exercise control over the remotely sited equipment, and to see at a glance from the indication display the state of that equipment.

(b) Line or radio circuits for the purpose of sending and receiving the command and indication information to and from the control office and the outstation.

(c) An equipment suitable for the purpose of processing the command and indication information into a form suitable for transmission over the bearer circuit, and to effect the transmission and reception of this information.

(d) A set of 'interface' equipment which may form part of (c), or be mounted separately, the purpose of which is to marry the controlling signals to the apparatus to be controlled.

All remote control systems break down into these four categories, each section being open to almost limitless variations.

The physical execution of the control positions are very much a question of taste, desks or consoles are favoured by some administrations and racks by others.

One form of control position based on modern components and techniques is indicated in Fig.1. It forms part of a modular system enabling a wide variation of arrangements to be created by using a minimum of standard units.

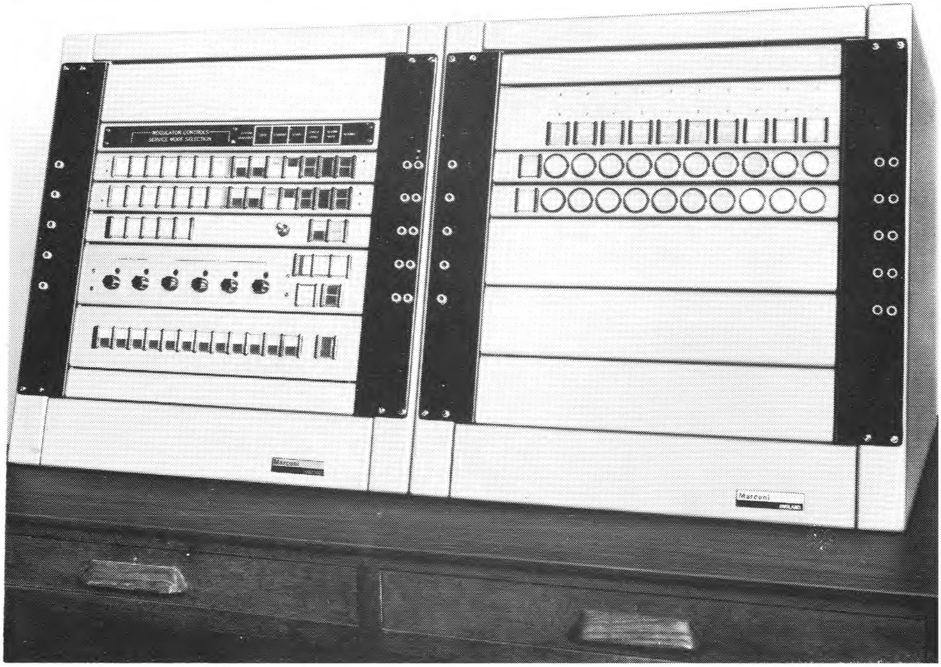

Fig.1. A pair of desk units showing controls for two transmitters and ten aerials. Frequency control units are shown for both full control in 100c/s increments, or any one of twelve preprogrammed frequencies

For processing and transmission of the command and indication information it is necessary to transmit several unique two-way 'messages' between the control office and the outstations. Various systems exist for this purpose but basically all are of parallel or series form.

2.1 PARALLEL FORM SYSTEMS

Parallel form systems employ d.c. or audio tone based signalling methods. With the d.c. system several metallic circuits have to be employed in order to present a number of unique bits of information with each bit corresponding to a command or indication. These messages are then encoded by connecting the circuits in various groupings, and use can be made of reverse polarity d.c. signalling to increase the number of different messages that can be sent. A system of this type is reliable and its simplicity and directness has much to commend it, but it is limited to operation over short distances. This limitation is due to the economic consideration of cable cost and the technical consideration of 'loop resistance'.

A tone based parallel system is similar to the d.c. system, but instead of several metallic circuits being necessary, only one circuit is required, and this need not be metallic. A group of audio tones is generated, and selections made from this group to create the unique messages required. These tone selections correspond to the various commands and indications, and are applied to the bearer circuit. Decoding is accomplished by the use of appropriate filter circuits at the receiving end.

Parallel tone or frequency division multiplex (f.d.m.) systems are usually 'one shot' in application. Information is only transmitted over the bearer circuit, when it is required to change the state of the controlled apparatus.

Precautions are taken to make certain that a received control or indication message has not been mutilated by interference or lost during transmission. It is common practice to cause the transmission time of each message to be longer than a certain prescribed minimum, say 100 m/s, to overcome transient interference, and also to transmit the message at least twice in rapid succession. This system employs a memory device to store the first transmission of each message for comparison with the second. If the second transmission does not coincide with the first, then the information is rejected and a request is made for retransmission.

Parallel tone systems are reasonably simple in principle and reliable in operation. They can be used over line or radio circuits, are almost instantaneous in operation and the cost is not high. Their main disadvantage is that they are limited in the number of messages which can be transmitted, usually about 20, but a recent development may make more than 100 messages possible. In addition they tend to be uneconomic in line usage by occupying most of a normal 300 c/s to 3 000 c/s bandwidth. Due to their 'one shot' approach, the system is quiescent between messages, and line failures can go unnoticed unless a guard tone is inserted.

2.2 SERIES FORM SYSTEMS

As with parallel form systems, either d.c. or audio signalling methods can be used in the series form.

D.C. methods use a metallic circuit with the information passed in series form by trains of pulses such as generated by a telephone dial, or electronically generated binary coded trains of long or short pulses.

It is in the field of tone based systems that series or time division multiplex (t.d.m.) systems come into their own. A common method of signalling by this means is to key a channel of a voice frequency telegraph (v.f.t.) system with suitably binary coded information.

Another form of t.d.m. equipment in common use is based on a continuous scanning principle, using electronic methods. Electronic circuits are arranged to scan a number of input points and to connect each of these in turn to a corresponding output point. These points are interrogated to determine the nature of the input information, e.g, control switch open or closed. The scan is used to frequency shift the carrier which is continuously transmitted over the bearer circuit. The state of each of the input points is conveyed to the outstations after scanning. Upon reception the information is stored by a memory register, generally taking the form of a group of suitably connected relays, one being allocated to each input point. The relays are used to store the state of each input point and to produce an output which is an analogue of the input, their contacts being used to perform the switching function at the

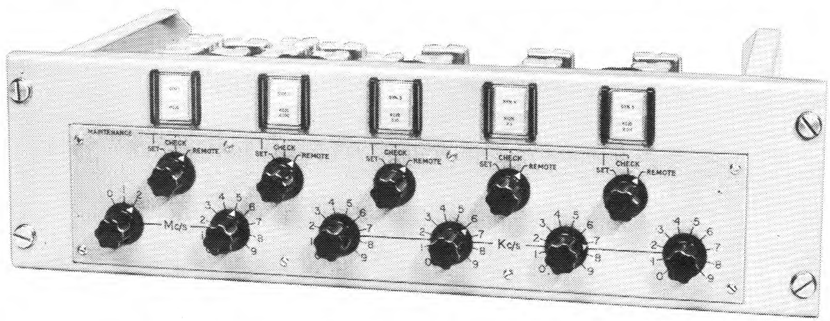

Fig.2. A synthesizer control interface unit, which translates the remote command messages into control signals to operate the motor-driven synthesizer. Local control and check facilities are provided

controlled equipment. Fig.2 shows a typical synthesizer control interface unit, as used in conjunction with the control of a frequency synthesizer where 68 control circuits are required to enable some 250 000 different frequency selections to be carried out remotely.

Various parity and other checks are made on the binary coded information after it has been received and before it is passed through to the memory register. This system is very reliable as any incorrect information received is rejected and not passed to the memory register.

The system employs a carrier, typically 2·5 to 2·7 kc/s which is keyed at 50 to 200 bauds, enabling frequencies between 300 c/s and 2·0 kc/s to be used for an engineer order wire (e.o.w.) circuit or other purposes. With this system using continuous scanning, line failures are quickly detected, and all displayed indications updated on a short time basis.

The system has the advantage that it can contain, if required, an unlimited number of control or indicator signals. The disadvantage is that as the number of control signals is increased, the longer will be the delay between the initiation and the execution of a command. In general, a delay of 2 or 3 seconds occurring on a system of sufficient size for a normal h.f. transmitting station would not be serious.

Economically speaking, t.d.m. systems are preferable to f.d.m. systems when the number of control signals exceed about 20. Below 20, possible future expansion and other factors should be considered before the relative cost can be evaluated.

3 CONVENTIONAL REMOTE CONTROL

It is common practice on h.f. transmitting stations to group the control functions of a number of transmitters at one central position on the station. This is often called remote control, but in effect it is extended control. Full remote control from a distance is more desirable, but it has not often been used, mainly due to the large number of controls which have to be operated.

One of the design objectives in the new generation of h.f. equipment has been to make it more suitable for full remote operation, by reducing the number of controls required. This has been achieved by the use of wideband and self-tuning amplifiers, improved frequency stability, com-

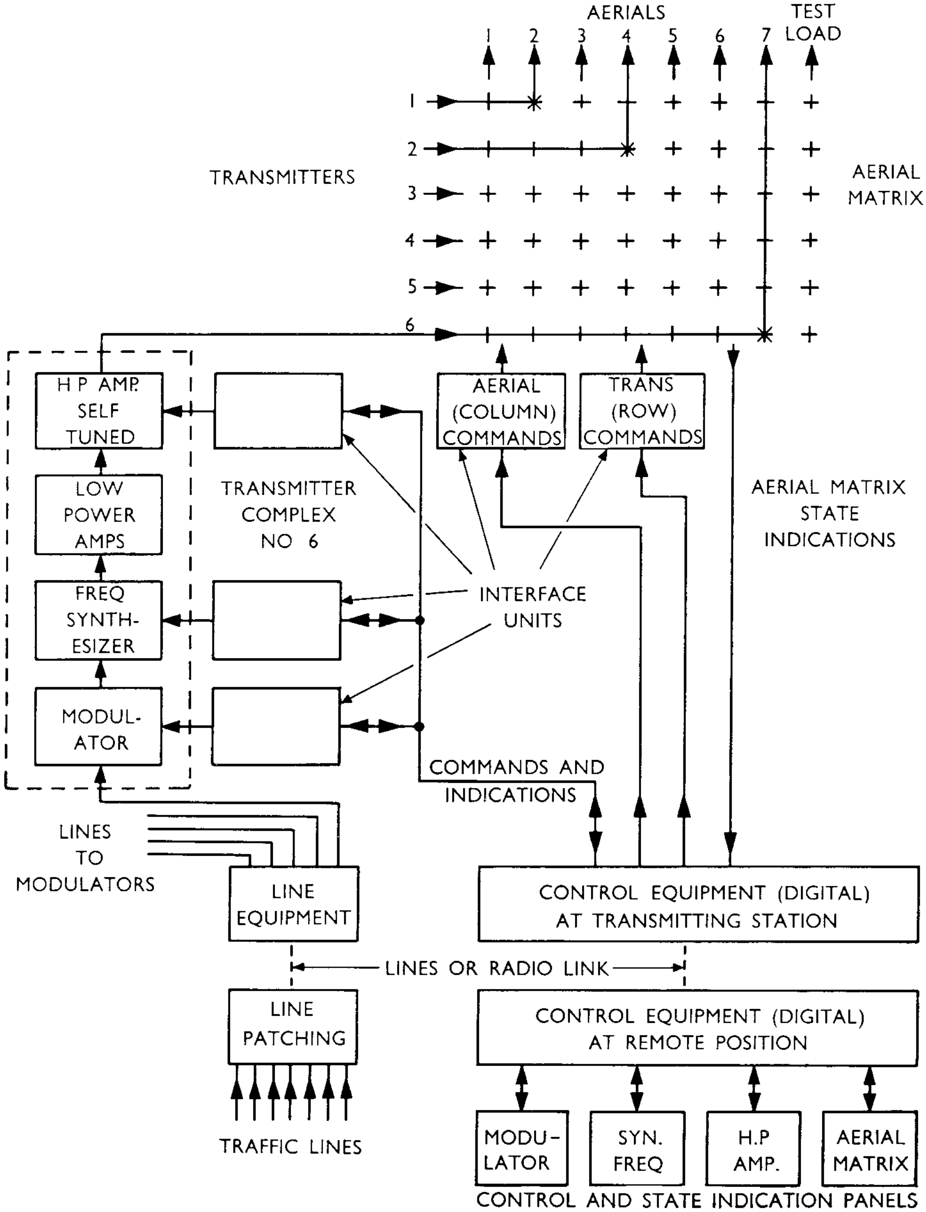

Fig 3. A remote control system for h.f. transmitting stations shown in block form. For simplicity only one transmitter is shown, but the system is applicable to multi-transmitter stations

prehensive modulators[5] and greater reliability. The increase in reliability has also been extended to equipment for the transmission and reception of the command and indication information, between the control centre and the outstation.

A remote control system has been introduced for use with these new h.f. equipments, which enables one man to have comprehensive control of all the necessary command and indication functions, from any distance. The system has been designed on a modular basis, which allows schemes of varying degrees of complexity to be assembled quickly and reliably from a small number of standard units. This type of construction reduces the range of spares which have to be held, and makes servicing easier, both valuable assets to the user.

Basically, the equipment is a t.d.m. digital transmission system, for which a range of suitable control panels has been designed. These control panels can be mounted either in a special desk unit or in any suitable 19-inch racking system, as required. All the commands necessary for comprehensive control are included, and there is a full range of 'state' indications by suitably captioned coloured lamps, as shown in Fig.1.

3.1 THE TRANSMITTING STATION

A block diagram of a remote control system applied to a transmitting station is shown in Fig.3. The remote operator has control of all the command functions including ON/OFF/STANDBY switching of the main h.f.

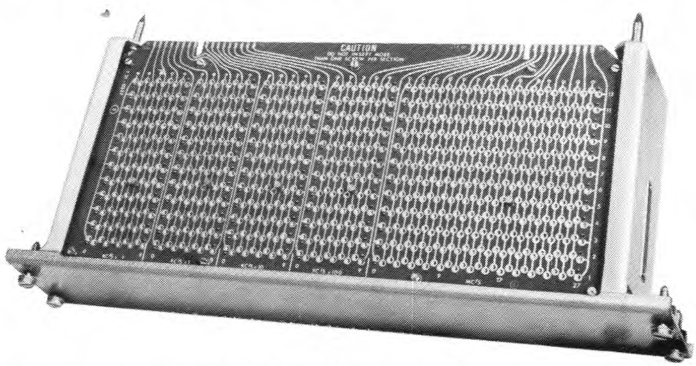

Fig.4. A frequency register unit which enables twelve frequencies to be preprogrammed by the insertion of small screw plugs into the correct co-ordinates

amplifier, and modulation mode selection of s.s.b, d.s.b, t.s.k. and c.w. Additionally, provision is made for either a fully comprehensive control of the frequency synthesizer in 100 c/s steps, or alternatively, a limited number of preset frequencies may be selected from a suitable control panel. A photograph of a preset frequency register is shown in Fig.4.

Complete control over the aerial switching matrix is given on a co-ordinate selection basis. A full readout of the state of the aerial exchange is provided, and in common with all other indications, this information is continuously updated on a short time basis.

Arrangements exist to display other information concerning the out-station, e.g, fire and intruder alarms, with a special panel provided for this purpose.

As the system is designed around a t.d.m. continuously scanning digital transmission equipment, it has the advantage of easy expansion if required.

3.2 THE RECEIVING STATION

The system used to control receiving stations remotely is very similar to that used for transmitting stations, many of the units being identical. Occasionally the transmitter and receiver controls will be grouped together, in these circumstances the power supplies and other compatible facilities may be shared by the two equipments.

Modern self-tuning receivers,[4] employing synthesizers, for either telegraph or telephone services, are used in remotely controlled receiving stations. A block diagram of a typical receiving station is shown in Fig.5, in which the remote operator has control of the following functions:

(a) Frequency control in 100 c/s increments or to pre-programmed frequencies.

(b) Selection of any one of five inputs from aerials, or from pre-patched aerial and multi-coupler systems.

(c) Mode switching of i.s.b, s.s.b, d.s.b, etc.

(d) Sideband inversion.

(e) Audio monitor line selection.

(f) A.F.C. on/off control.

(g) Aerial input attenuator

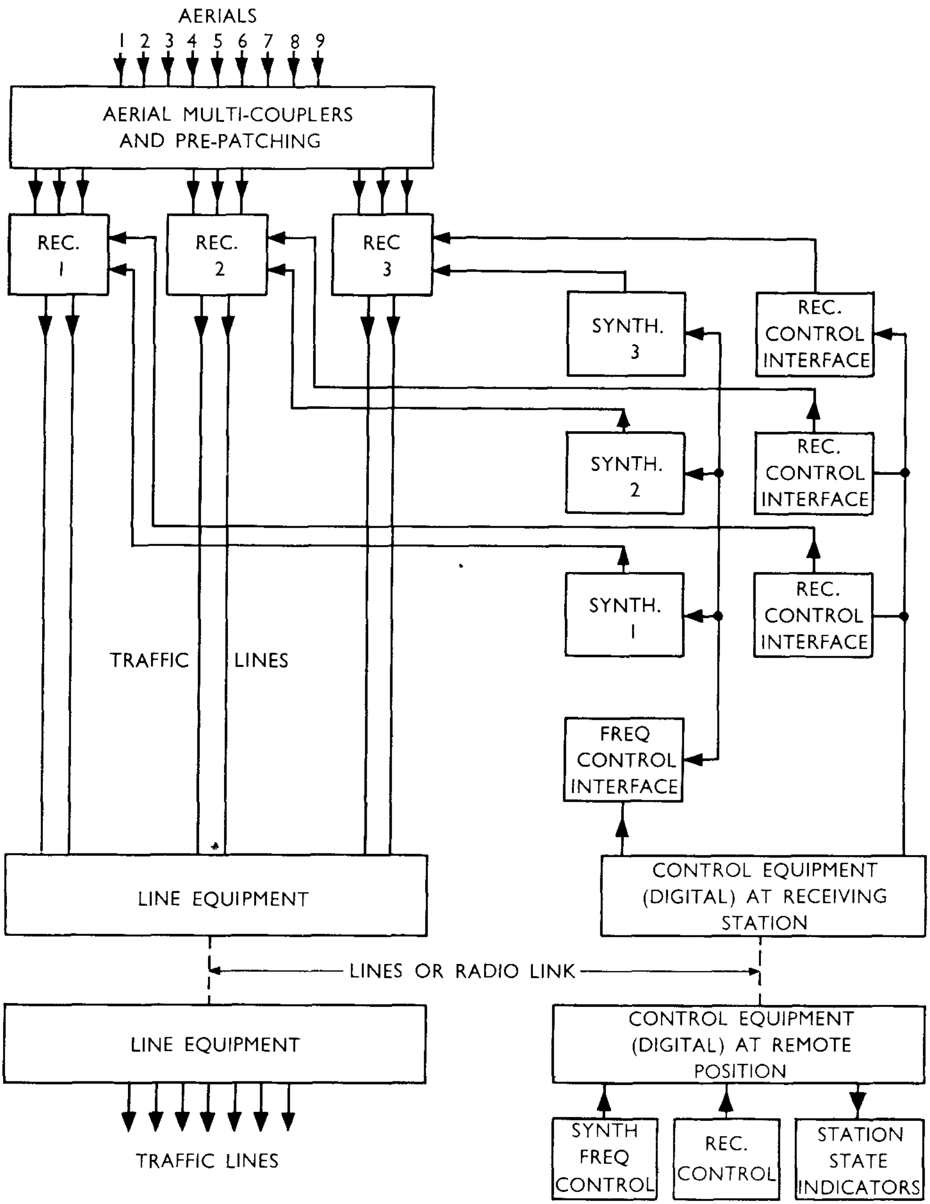

Fig.5. A remote control system for h.f. receiving station shown in block form

3.3 THE CENTRAL CONTROL POSITION

Remote control of transmitting and receiving stations enables complete control to be established at some convenient location, up to considerable distances from the controlled equipment. A system of this type has many economic and other advantages, but it does not eliminate the possibility of human error by the watchkeeping staff, usually one man.

The watchkeeper has to make the necessary decisions required to bring about effective and efficient control at the outstation over all the features mentioned previously at the controlled outstation. Although the whole system is designed to be self protecting should errors occur, it is nevertheless possible for a watchkeeper to make incorrect decisions and to set up wrong conditions, e.g, incorrect frequency or aerial.

A common feature of all h.f. communication systems is that frequency changes tend to be concentrated in short periods of the day. Where a single watchkeeper has remote control of an outstation containing a large number of equipments, the possibility of human error during these short periods is considerable, especially when he controls both transmitters and receivers.

4 REMOTE CONTROL OF SEMI-AUTOMATIC TRANSMITTING STATIONS

Many of the decisions and subsequent actions of the watchkeeper can be carried out by automatic devices, introducing the concept of automatic remote control of transmitting and receiving stations. In a system of this type the watchkeeper no longer has to control each and every function of each and every piece of equipment, in order to set up a traffic route through the station between the lines and the aerials. In a transmitting station, the functions which an automatic system can take over from the watchkeeper include the following:

(a) Selection and interconnection of unengaged equipment to form a chain suitable for handling a particular service.

(b) Connect a monitoring device to the correct equipment selected to carry the service.

(c) Provide a continuous check of the equipment performance in the service chain and replace any unit found faulty.

(d) Monitor the traffic on incoming lines and report faults indicated as being external to the transmitting station.

With these functions effected automatically, the watchkeeper's tasks are reduced to the point where he only operates service switches in accordance with a schedule and performs monitoring checks. Alternatively, the watchkeeper is directed by, or even replaced by, the traffic controller who, in all probability, will be near at hand. From the operation of the service switch, the setting up of the traffic requirements and route through the station is entirely automatic.

This method of operation is based on the concept that one must employ a given aerial or group of aerials, a given modulation mode and a given frequency for a given service and time of day. All of these variants can be preprogrammed, so that with the correct incoming traffic, all the operator has to do is to press a button and the automatic system does the rest.

Having reached the stage where all the requirements of each service to be transmitted are known, these can be preprogrammed and the necessary information set up in various register devices. It is only the parameters such as frequency, modulation mode, etc, that need be preprogrammed, so the allocation of equipment need not in itself be predecided, with the exception of the aerial. The automatic system selects the appropriate units which are available, i.e, not in use or being serviced, and connects them together to provide a complete transmission system at the station, from incoming lines to aerials. The necessary items of preprogrammed information, such as frequency and modulation mode, are switched into the appropriate sections of the equipment as they are engaged by the automatic system.

The system is also arranged so that a check is made for performance, continuity and power levels, before it is switched to traffic.

It follows from this description that there must be sufficient equipment available for automatic selection. Thus an automatically controlled station must have, in common with manned stations, spare equipment available to avoid traffic interruptions and to allow adequate servicing to be carried out.

With an automatic service of this type it is not sufficient just to replace the human element to select and connect the equipment together. It is absolutely necessary to provide an alternative for the alert human eye and ear, once the equipment is in operation. This means that comprehensive monitoring equipment has to be introduced, having two functions to perform:

(a) To maintain a continuous check on the performance of the equipment in each transmitting system, to give warning of faulty equipment and replace when necessary.

(b) To monitor the incoming traffic continuously, enabling system faults to be reported as outside the station, or in conjunction with (a) to localize the faults within the station.

A comprehensive 'station state' display panel features largely in a system of this type, giving a continually updated readout. The readout indicates the service in use and all equipment which has been engaged to provide service paths through the station. Equipment 'on fault' is indicated, together with any not available due to being 'on maintenance'.

A universal monitoring receiver with an automatically tuned synthesizer can be built into a system of this type, which could also be preprogrammed, so that it automatically tunes to the required frequency and switches to the demodulation mode of any 'service'. Means exist for breaking down the aggregate signals for such a receiver so that individual channels may be compared with the station line input, thus giving a complete loop check.

The automatic system based on the service concept briefly described, has as its starting point the aerial from which the selected service is to be radiated. The other fixed parameters for this service, such as frequency, modulation mode and transmitted power, are arranged on a preprogrammed basis and automatically associated with that aerial. Clearly some form of mechanism is required in order to select the various items of equipment and to make the necessary connections.

Various possibilities exist to achieve the necessary degree of automatic control; perhaps the most obvious one is to employ electromechanical devices, such as uniselectors, to perform the various selecting functions whenever a change of state is required. This method is only satisfactory with adequate and specialized maintenance, therefore such systems are best avoided.

A more satisfactory method uses the in-built self-hunting property of the matrix used for aerial selection. By suitably connecting the control circuit of the pneumatically driven aerial exchange to use the co-ordinate method of selecting aerial switches in the matrix, the aerial exchange can be made to select a given marked column (aerial), and to hunt for an unoccupied row (transmitter) of the matrix (Fig.6).

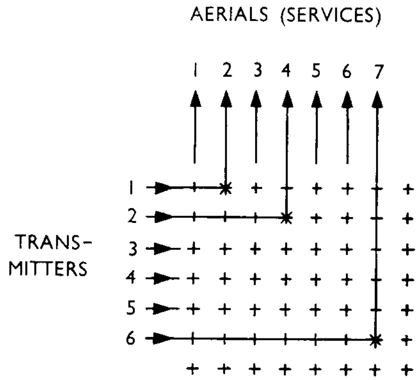

Fig.6. Feeder matrix showing transmitters 1, 2 and 6 connected to aerials 2, 4 and 7 with services 2, 4 and 7 respectively

By linking the services to the aerial columns of the matrix, the device is made to hunt for an unoccupied transmitter row. Thus the complete transmitter equipment for any particular traffic route can be brought into operation by the remotely controlled aerial switch selection.

No additional automatic hunting is necessary, but small relay matrices are required which are miniature replicas of the aerial switching matrix. For reliability these small matrices are constructed with maintenance-free reed relays.

These relay matrices are then arranged to be switched as slaves to the main exchange, so that the pattern of selection existing on the aerial exchange matrix is repeated in these relay matrices. They can then be used to perform such duties as traffic line switching, frequency selection, modulation mode selection, etc. All of these functions are dependent upon one fixed parameter as defined by the aerial selected, and one variable parameter the transmitter selected.

The frequency and modulation mode selection can be performed in co-operation with a frequency register, Fig.4, and a modulation mode register. These registers store the preprogrammed information ready for use in setting up the frequency synthesizer and the modulators when they have been picked up by the automatic system.

A reed relay matrix for connecting the incoming traffic lines to the modulators is shown in Fig.7, and a similar matrix for supplying the frequency synthesizers with information from the frequency registers is shown in Fig.8. Note that the positions selected on these two matrices are identical with those selected on the main aerial exchange, Fig.6.

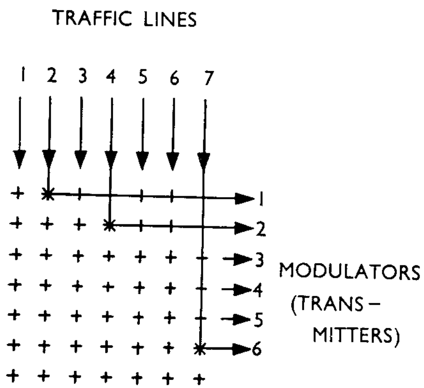

Fig.7. Matrix for connecting traffic lines to the modulators, which are directly connected to the corresponding transmitters

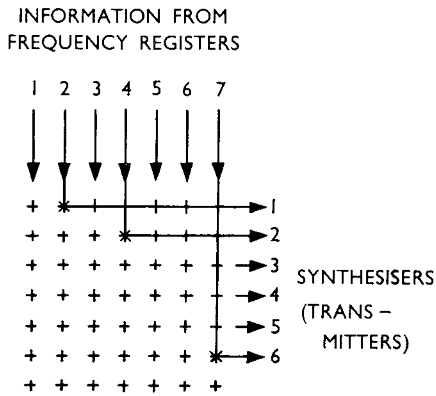

Fig.8. Matrix for supplying the synthesizers with control information from the frequency registers

A block diagram, Fig.9, illustrates the more important units which feature in this form of control system. The 'pattern matrix' is a primary slave matrix coming directly from the aerial exchange which is used to switch all of the other matrices.

It will be seen that each modulator and frequency synthesizer is part

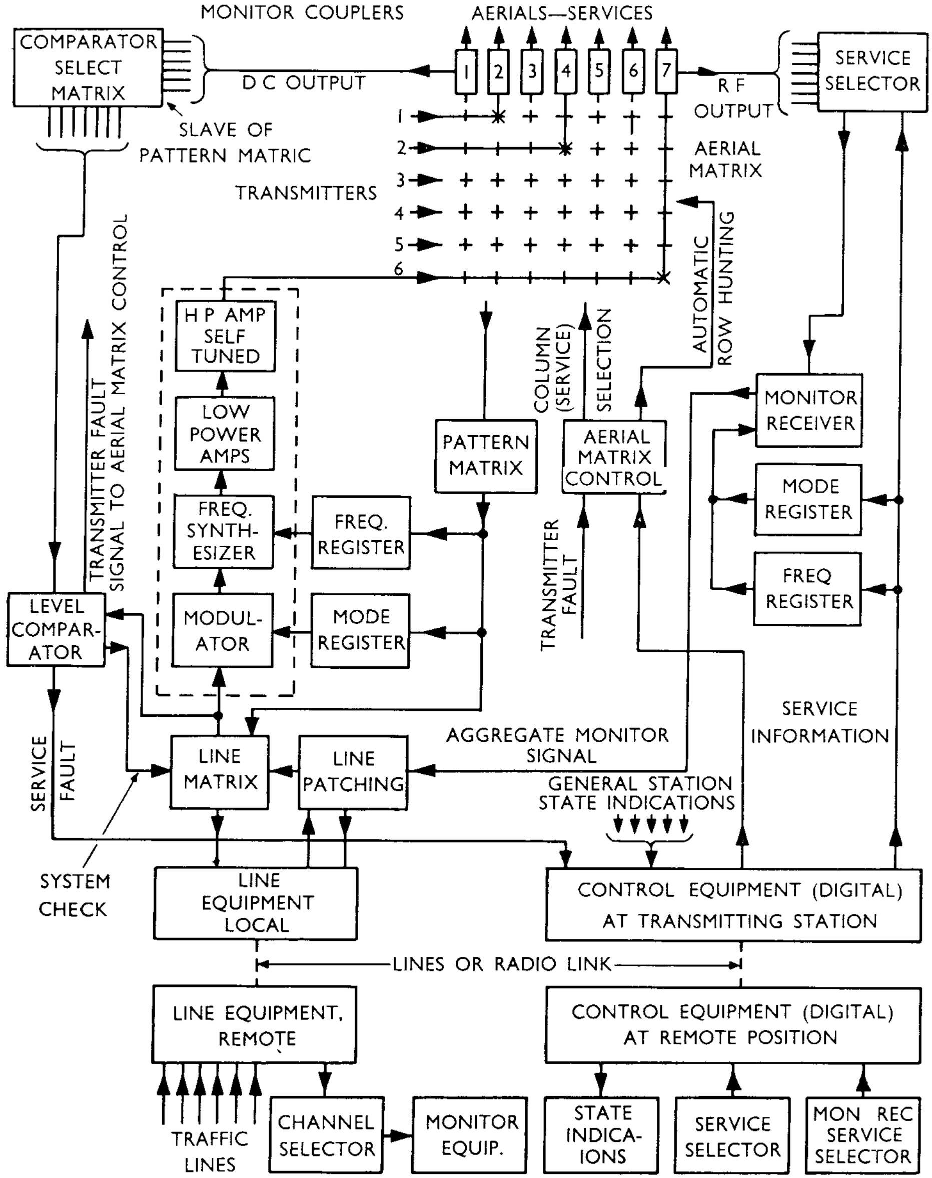

Fig.9. Block diagram of a transmitting station with automatic remote control, operating on a digital basis. Only one transmitter is shown for simplicity

of a single transmitter complex, so that complete transmitter chains are selected automatically.

An automatic system as outlined is suitable for control from either a central position at the transmitting station, or from a remote position by using the digital techniques described. This is an obvious advantage to the user, who may eventually require automatic remote control, yet for economic or other reasons, does not require it in the initial installation.

With this system, the functions required are far fewer than would be needed for a fully comprehensive remote control system, where all the individual controls are at the remote position. Considerably more equipment can be controlled in a given time, as far fewer messages are required for each equipment.

5 REMOTE CONTROL OF SEMI-AUTOMATIC RECEIVING STATIONS

Although a degree of automatic control can be used for receiving stations, it is not practical to apply it to the same extent as in the case of transmitting stations. This is due to the unpredictable hazards caused by variable propagation conditions and the present congestion in the h.f. bands.

To overcome these difficulties, receiver operators have to resort to various stratagems to maintain traffic. The measures taken may involve tuning shifts to follow unstable signals, abnormal setting of the input attenuators to minimize distortion caused by interference, and ' off beaming ' by aerial selection to discriminate against unwanted signals.

It is desirable to maintain the facility of controlling the individual functions by the remote watchkeeper. Not all services require the application of the watchkeeper's craft to maintain traffic, for by adequate monitoring, good services can be left to an automatic device, leaving watchkeepers more time to nurse the difficult circuits.

A method of applying automatic monitoring is shown in the block diagram Fig.10, in which the receiving station depicted employs automatic remote control of aerial selection, a.f. and d.c. line selection. The remote receiver controls are as for the system described in Section 3.2.

Each receiver has in its output lines a monitor unit, employing many

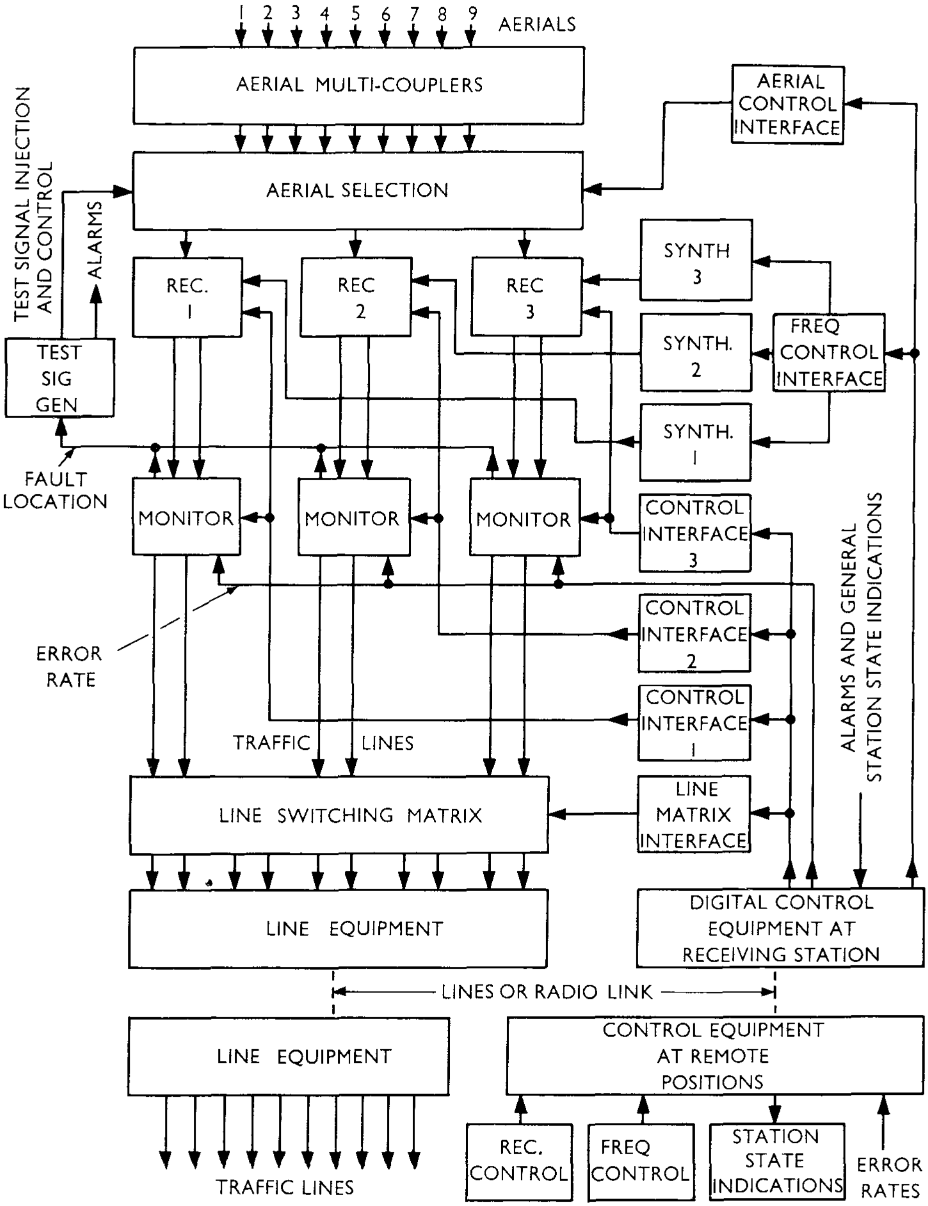

Fig.10. Block diagram of a receiving station with automatic remote control, operating on a digital basis

of the devices used in the transmitting unit described in Section 3.1. The monitor units are set up by the remote control interface equipment to the appropriate modulation mode used in the associated receiver.

Alarms generated by the monitor are for loss of carrier over a set period, a persistently low signal level, or loss of modulation, and the error count from the ARQ equipment can also be used. Triggering of the monitor alarm circuits indicates several possibilities; the receiver, the receiving aerial or multi-coupler may be faulty, propagation conditions may be bad, or the distant transmitting chain has failed.

Receivers can be checked by the injection of a local test signal or by substitution of another receiver. Aerial or multi-coupler faults usually make their presence known by affecting more than one receiver.

The alarm signal arriving at the test signal generator contains information such as the receiver identity, tune frequency, modulation mode and gain setting. A suitable test signal is then set up by the generator and injected into the correct receiver input. Provided this signal is received intact by the monitor, a 'service fault' is signalled to the watchkeeper. In the event of the test signal being lost or mutilated, an 'equipment fault' will be signalled to the remote control point. Where diversity receivers are employed, all the receiver inputs of the group will need to be tested in turn.

The test signal generator is based on a standard transmitter drive with added modulation source and an automatic attenuator.

6 DEVELOPMENT TRENDS

It has been shown that semi-automatic and remotely controlled transmitting stations can reduce the operator's function to opening or closing a service, changing frequency and carrying out monitoring checks on performance.

Some services could be opened or closed by a simple timing device, while another thought is that prefix or suffix coded signals on traffic could perform this function in much the same way as a route is selected by automatic message switching.

With receiving stations further automatic controls will depend on general improvements in h.f. equipment performance and operating discipline. Obsolete systems of poor frequency stability and linearity will have to be replaced, while further improvement would result by restricting the beam width and side lobe levels of transmitting aerials. The development of a broadband narrow beam electrically steerable receiving array would give the system designer a further weapon against interference. The principle of using no more transmitter power than is required to maintain a good service, combined with automatic control of transmitter power, using ARQ systems as the reference, would further improve matters.

The decision to change frequency on point-to-point services requires careful assessment of many factors, particularly the often erratic nature of propagation conditions. Other factors which the traffic controller has to consider are the error rate or distortion on an established circuit, the traffic priority and the state of other receivable transmissions. A simple computer could make the decision and command a frequency change, particularly with information fed in from ionospheric soundings.[6]

At the present state of the art, automatic monitoring systems are practicable which will take action on all probable faults except large intermodulation products developed whilst a system is carrying traffic. Until this problem is solved, monitoring by an operator will still be required.

7 CONCLUSIONS

Current staffing problems and the need for centralization are responsible for the increased demand for remote control systems. Equipments of proven reliability and versatility are now available so that systems covering every aspect of remote control can be readily engineered.

The marriage of automatic and remote control methods reduces the demands on skilled watchkeepers and cuts circuit outages. Thus the application of automatic remote control to h.f. communication systems offers many advantages to the user.

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Joining The Marconi Company in 1957 as an installation engineer, he subsequently became a site engineer, his work involving the planning and installation of h.f. projects throughout the world.

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