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The Engineering Facilities of the BBC Monitoring Service

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BRITISH BROADCASTING CORPORATION

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FOREWORD

THIS is one of a series of Engineering Monographs published by the British Broadcasting Corporation. About six are produced every year, each dealing with a technical subject within the field of television and sound broadcasting. Each Monograph describes work that has been done by the Engineering Division of the BBC and includes, where appropriate, a survey of earlier work on the same subject. From time to time the series may include selected reprints of articles by BBC authors that have appeared in technical journals. Papers dealing with general engineering developments in broadcasting may also be included occasionally.

This series should be of interest and value to engineers engaged in the fields of broadcasting and of telecommunications generally.

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THE ENGINEERING FACILITIES OF THE BBC MONITORING SERVICE

SUMMARY

At the conclusion of the war in 1945 the BBC Monitoring Service—started as a listening unit at Evesham in August 1939, and transferred as a comprehensive Service to Caversham Park, near Reading, in March 1943—was to a considerable extent provided with engineering equipment obtained during the war years.

Varied in type and origin, much of this British and American equipment has been replaced in recent years, mostly by British-made equipment selected or specified to meet as closely as reasonably possible the operational requirements of the Service.

The object of this monograph is to give an up-to-date description of the engineering facilities of the Service, the war-time facilities of which were described in part in the *BBC Quarterly*, Vol. II, No. 2, July 1947.

1. Introduction

The BBC Monitoring Service, at Caversham Park near Reading, consists of three main departments—the Reception Unit which is responsible for the basic operation of monitoring and transcription, the News Bureau, and the Reports Department, which select and edit the transcribed material for the numerous official and other recipients of the service. The necessary engineering facilities, including the operation of a separate receiving station at Crowsley Park where broadcasts are picked up and fed to the monitors by line, are provided by a section of the BBC Engineering Division.

Reception of voice, morse, hellschreiber, and teletype transmissions is carried out at both Caversham and Crowsley. Strong signals are received directly by the monitors at Caversham. However, as the site there is restricted in size and is subject to a fair level of electrical interference from Reading, weak and long-distance signals are received by engineers at Crowsley, which has ample space for high-gain directional aerials, and is virtually free from electrical interference.

2. The Caversham Amplified Aerial System

This was formerly in duplicate to reduce the possibility of a complete loss of aerial feeds due to fault conditions or enemy action. Local plans to build a housing estate close to the aerial site made it necessary to move this, and the present arrangements provide only one set of aerials with switching facilities arranged to minimize the possibility of a complete loss of aerial feeds due to fault conditions.

Operationally it is necessary for all Caversham receiving positions to be able to receive from all directions and at all broadcast frequencies. This requirement is met by the use of a number of aerials and associate filter amplifiers, which together cover all broadcast frequencies. The use of filter amplifiers lessens the number of signals entering the amplifiers and in consequence lessens the tendency towards the production of intermodulation terms. This tendency is further reduced by confining the bandwidth to one octave, because square law intermodulation products of the form $f1 \pm f2$ produced within the amplifiers are automatically placed outside the octave band. The employment of a number of aerials and associate amplifiers to cover a wide frequency spectrum also improves aerial efficiency and lessens the effect of amplifier noise.

Aerials and associate amplifiers covering seven octaves and one near octave are used at Caversham and cover all frequencies between 100 kc/s and 27 Mc/s excepting 400–500 kc/s. Frequencies below 150 kc/s are covered by one aerial and an associate frequency convertor.

Nine approximately omni-directional aerials are supported by four stayed lattice-steel masts, each 100 ft high, and arranged in a square of 220-ft sides. Three of the aerials are horizontal 'V's, consisting of wire cages, and are cut, one each for the frequency bands, 16–27 Mc/s, 8–16 Mc/s and 4–8 Mc/s. These three aerials each form part of triatics slung at a height of 87 ft between adjacent masts, the whole forming a square of triatics. Five of the remaining aerials are simple long-wire semi-vertical aerials hung from the triatics, and cover the frequency bands, 2–4 Mc/s, 1–2 Mc/s, 500–1 000 kc/s, 200–400 kc/s, and 100–200 kc/s. The ninth aerial is employed for frequencies below 150 kc/s and is in the form of a 'T' in which the horizontal members form part of adjacent triatics of the square of triatics.

2.1 *Aerial Connection Arrangements*

A small metal kiosk and buried earth plate are positioned within the square of masts to facilitate direct connection of the long-wire aerials and the 'T' aerial to a tubular steel gantry placed close to the kiosk. Balanced-twin open-wire vertical 600-ohm feeders from each of the horizontal 'V' aerials are also connected to this gantry, via similar open-wire feeders mounted on steel poles. All of the aerials and feeders are led into the kiosk via pyrex lead-through insulators and are connected there to aerial coupling units.

Aerial coupling units for the long-wire aerials and 'T' aerial each consists of a reactance designed to neutralize the aerial reactance at mid-band, followed by a transformer which transforms the resulting resistive impedance to that suitable for 100-ohm coaxial connection. The coupling units for the horizontal 'V' aerials consist simply of balanced 600-ohm to unbalanced 100-ohm transformers. All aerial and feeder connections are provided with lightning arrestors at the kiosk, and in addition the 600-ohm connections to the coupling unit of the horizontal 'V' aerials are fused. The kiosk is provided with thermostatically controlled heating, and in addition with lighting and a telephone for maintenance purposes.

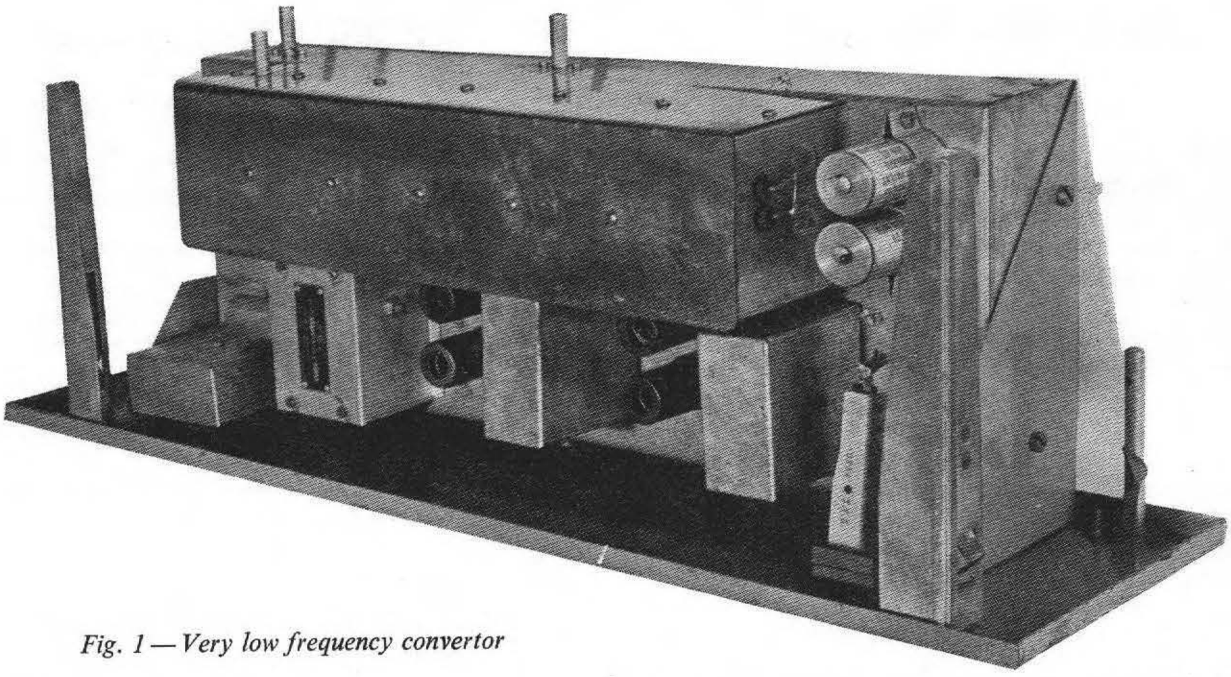

Fig. 1 — Very low frequency convertor

2.2 *Aerial Amplifiers*

Nine buried coaxial cables connect the outputs from the aerial coupling units to the original brick-built aerial amplifier hut and thence to radio-frequency jackfields and coaxial changeover relays. The latter are remotely operated from the main building and enable the eight aerials covering the frequency band 100 kc/s–27 Mc/s to be connected to either of two sets of eight aerial amplifiers, one set operative and the other spare.

The two sets of aerial amplifiers each comprises seven two-stage octave-band amplifiers and one three-stage near octave-band amplifier. Six of the two-stage amplifiers have a minimum gain of 25 dB and cover the frequency bands 100–200 kc/s, 200–400 kc/s, 500–1 000 kc/s, 1–2 Mc/s, 2–4 Mc/s, and 4–8 Mc/s. The seventh two-stage amplifier has a minimum gain of 30 dB and covers the band 8–16 Mc/s, while the three-stage amplifier has a minimum gain of 35 dB and covers the band 16–27 Mc/s. Transforming band-pass filters are used as couplings at the amplifier inputs and outputs and as intervalve couplings. The amplifier output coupling is mid-series terminated to provide a high impedance outside the amplifier pass-band. The latter arrangement permits the outputs of amplifiers of non-adjacent bands to be paralleled without mutual degradation.

The two sets of amplifiers have their outputs paralleled together to form two separate grouped outputs per set. The frequency coverage of the group outputs is as follows:

Group 'A'	*Group 'B'*
16–27 Mc/s	8–16 Mc/s
4–8 Mc/s	2–4 Mc/s
1–2 Mc/s	500–1 000 kc/s
200–400 kc/s	100–200 kc/s

These two grouped outputs ,from either the operative set of amplifiers or the spare set, are connected via radio-frequency jackfields and coaxial relays to buried coaxial cables connecting to the main building. Again the coaxial relays are remotely operated from the main building so that either the normal or spare set of amplifiers may be used. In addition each set of amplifiers may be powered separately or together by relays operated from the main building. Thus facilities exist for interchanging the two sets of amplifiers without loss of service. Test and maintenance facilities, together with spare power packs, are provided at the aerial amplifier hut.

2.3 *Main Building Termination and Distribution System*

At the main building the two group coaxial cables are terminated on radio-frequency jackfields. There they are linked to hybrid transformers, each of which provides two similar outputs, one for each half of the building, that is two group cables to each. Unbalanced to balanced transformers covering all frequencies between 100 kc/s and 27 Mc/s are inserted immediately following the hybrid transformers, and thence connected via screened and balanced cables to distribution units located centrally in the areas to be fed. The conversion to balanced screened cable is made to minimize the effect of any electrical interference present in the main building.

Four identical distribution units are employed, one each for groups 'A' and 'B' at each of the two areas fed. These units comprise 100-ohm balanced to 3·3-ohm balanced transformers covering all frequencies between 100 kc/s and 27 Mc/s, with sixty pairs of 50-ohm resistances from the 3·3-ohm winding arranged to provide sixty balanced 100-ohm outputs. Thus the single grouped input to each distribution unit is divided into sixty separate balanced outputs, the overall attenuation of the unit to each output being 20·8 dB, and the attenuation between any pair of outputs 41·6 dB. Unused outputs are terminated at the unit in 100-ohm resistances.

Each receiving position is provided with a feed from the area group 'A' and group 'B' distribution units. These balanced feeds enter aerial switch boxes placed close to receivers, which can thereby be connected to either group at will. The switching arrangements provide 100-ohm resistance termination of the unused feed. Two spare positions, one balanced and one unbalanced, are available for special use, only the former being resistance terminated when not in use. A balanced 100-ohm to unbalanced 100-ohm transformer provides for connection to the input of the unbalanced receiver.

The ninth, 'T', aerial employed below 150 kc/s is connected directly via jackfields in the aerial amplifier hut, and a buried coaxial cable, to the main building. At this point it is connected to a frequency convertor illustrated in Fig. 1 consisting of a balanced push-pull amplifier stage followed by a balanced push-pull frequency convertor with an included 500-kc/s crystal-controlled oscillator. This converts the input frequency band of 15–150 kc/s to 515–650 kc/s. The output of the convertor is taken, via an unbalanced to balanced transformer and screened balanced-twin cable, close to all of the points to be fed. Suitable high-impedance bridging transformers followed by double-screened coaxial cable are used to connect to each receiver *en route*. Considerable care is taken to prevent break-through of unwanted signals at unconverted frequencies.

Very low-frequency signals are at times received at Caversham using multi-turn loop aerials a few feet in diameter. These are either direct coupled to receivers via tuned transducers, or tuned across the high impedance grids of single-stage push-pull amplifiers, the outputs of which are connected to receivers.

3. Receivers

3.1 *Single-superheterodyne Receivers*

British made general purpose communications receivers are employed and conventional single-superheterodyne receivers by one manufacturer form the greater proportion of those in use; a receiver of this type is shown in Fig. 2. Fourteen valves are used in this receiver, which covers in six switched bands all signal frequencies between 150 kc/s and 30 Mc/s except frequencies between 385 kc/s and 510 kc/s. The circuit consists of two radio-frequency stages, frequency changer and separate local oscillator, two 455-kc/s intermediate-frequency stages, detector, audio and output stages. Provision is also made for radio-frequency a.v.c. delay, intermediate-frequency a.v.c. delay, a.v.c. amplifier, noise limiter and beat-frequency oscillator. Power arrangements include a rectifier, smoothing valve and voltage regulator, all self-contained within the receiver. A crystal-controlled calibrating oscillator is an optional extra. All of the usual controls are provided, including a dial lock, gain controls for r.f., i.f., and a.f., a six-position selectivity switch and crystal phasing control, and controls for the beat-frequency oscillator and limiter. Separate toggle switches are provided for send-receive, mains on-off, a.v.c. on-off, calibrator on-off, audio filter in-out, speech-music, and beat-frequency oscillator on-off. Connections at the rear of the receiver include an a.v.c. outlet, and an i.f. outlet for use in receiving frequency-shift keyed signals. In its price range this general-purpose communications receiver is outstanding and well meets monitoring requirements, particularly in the reception of voice signals.

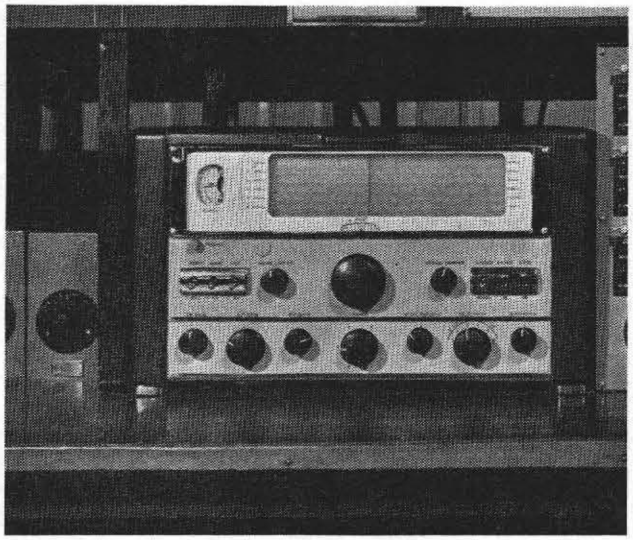

Fig. 2 — Single-superheterodyne receiver in use at Caversham

3.2 *Double-superheterodyne Receivers*

A small number of double-superheterodyne receivers by a second manufacturer is used for the reception of morse signals and the type is illustrated in Fig. 3. These receivers employ an external power supply unit to reduce temperature changes in the receiver. Fourteen valves are used in the receiver, which covers in four switched bands all signal frequencies between 2 Mc/s and 32 Mc/s. The circuit consists of two radio-frequency stages, first frequency changer and separate local oscillator, the latter being L.C. or crystal controlled at six switched frequencies. The first frequency changer is followed by a pair of tuned inductively coupled coils forming the first intermediate-frequency filter centred on 1 600 kc/s. The filter connects to the second frequency changer, which is provided with a separate local oscillator centred on 1 135 kc/s and provided with a fine tuning control with a range of ± 4 kc/s. The second frequency changer is followed by 465 kc/s intermediate-frequency stages, detector and audio and output stages. Provision is also made for a.v.c. with alternative time constants, noise limiter, beat-frequency oscillator and a crystal-controlled calibrating oscillator. All the normal controls are provided, including h.f. and a.f. gain controls, a four-position selectivity switch, selection of L.C. oscillator or crystal oscillator using any one of six crystals, and fine tuning by means of the control on the second local oscillator. An operational switch is employed for a.v.c. on-off, beat-frequency oscillator on-off, and limiter on-off. A separate switch and associated meter enables individual valve feeds to be checked. The meter may also be used as a tuning indicator. Connections at the rear of the receiver include a.v.c. and 465-kc/s i.f. outputs,

Marconi's Wireless Telegraph Company Limited

Fig. 3 — Double-superheterodyne receiver in use at Caversham

and provision for diversity operation in which two or more receivers are fed from an external oscillator. The receiver is a good one for general communications purposes, and even when operated without crystal control of the first local oscillator is more frequency stable than average.

3.3 *Special-purpose Receivers*

A small number of receivers of an unconventional type, shown in Fig. 4, by a third manufacturer is used for reception of some high-frequency radio-teletype signals. These receivers use twenty-three valves in all and cover all frequencies between 500 kc/s and 30 Mc/s, with slight degradation below 1 Mc/s. The general form of the receiver is given in the block schematic, Fig. 5, the upper, signal chain, including a single tunable radio-frequency amplifier followed by three frequency changers, associate band-pass intermediate-frequency filters and amplifiers, and final detector, audio and output stages. A beat-frequency oscillator and crystal-controlled calibrating facilities are also provided. The lower chain of the block schematic, consisting of a 1-Mc/s crystal-controlled oscillator, harmonic generator and associate frequency changer, filters and first and second variable-frequency oscillators, is concerned only with the provision of oscillator supplies to the three frequency changers of the signal chain. Because the first variable-frequency oscillator is used directly to drive the first signal frequency changer, and the same oscillator is combined with the output from the harmonic generator to drive the second signal frequency changer, it follows that the output from the latter will possess the frequency accuracy and stability of the 1-Mc/s oscillator harmonics. Thus the overall frequency accuracy and stability of the receiver are determined largely by that of the second variable-frequency oscillator, which, being relatively low in frequency and temperature compensated, will be of secondary importance from the point of view of frequency stability of the receiver as a whole. To give a clearer understanding of the way in which this receiver operates, some signal frequencies are tabulated together with the resulting frequencies at various points in the receiver.

Location	*Frequency, Mc/s*						
Input	30	29·6	29	29	1	·5	0
Harm. Gen.	32	32	32	31	3	3	3
VFO 1	69·5	69·5	69·5	68·5	40·5	40·5	40·5
FC1 Out	39·5	39·9	40·5	39·5	39·5	40	40·5
FC2 Out	2	2·4	3	2	2	2·5	3
VFO 2	2·1	2·5	3·1	2·1	2·1	2·6	3·1
FC3 Out	·1	·1	·1	·1	·1	·1	·1

It will be understood from the foregoing that the receiver operates on a decade system in which the first variable-frequency oscillator selects a megacycle band of frequencies and the second variable-frequency oscillator provides accurate tuning over the selected band. Thus no band switching is employed. Aerial input arrangements are complicated by the receiver design, and comprise a five-position switched aerial attenuator, followed by input tuning arrangements consisting of a seven-position aerial range switch which has one wide-band position and, in association with an aerial tuning control, six tunable positions covering ·5 Mc/s to 30 Mc/s in five octave bands and one near octave band. The final, third, signal intermediate-frequency amplifier stages are preceded by a crystal-lattice filter network and L.C. filter with six alternative band-widths. An additional intermediate-frequency stage provides an independent output at 100 kc/s. Separate signal and a.v.c. diodes are used, and alternative switched time-constants are available. Two independent audio-frequency stages are provided. A regenerative divider fed from the 1-Mc/s crystal oscillator is used to provide signals at 100-kc/s intervals for scale calibration. All the usual controls are provided, including a lock on the 'kilocycle' tuning control. A meter is provided and may be switched to indicate radio or audio levels. The receiver is well engineered and very satisfactory in operational use, its frequency accuracy and stability being of great value for reception of radio-teletype signals and also for search and supervisory purposes. Its speed of band-change is also a great asset.

4. Recorders and Transcribers

Several hundred recordings of foreign news bulletins, with an average duration of fifteen minutes, and varying between ten and thirty minutes or more, are made each twenty-four hours at Caversham. All require accurate transcription in whole or in part.

General requirements for the recorders and transcribers, which are illustrated in Fig. 6*a* and *b*, are reliability, ease of filing and mailing the recordings, and low operating costs. Requirements for the recorder are that it must be provided with automatic volume control, be suitable for recordings in excess of fifteen minutes, provide good intelligibility and be capable of remote operation. The transcriber must be provided with foot operated start-stop and back-space facilities, rapid finger selection of passages at any point in the recording, and a speed control capable of adjustment above and below the fixed recording speed.

British- and American-made office dictation equipments meeting these requirements fairly well became available in 1951 and, following operational tests, the British-made equipment was selected and used to replace the worn wax-cylinder equipment obtained before and during the war.

Raca Engineering Limited

Fig. 4 — Special-purpose receiver in use at Caversham

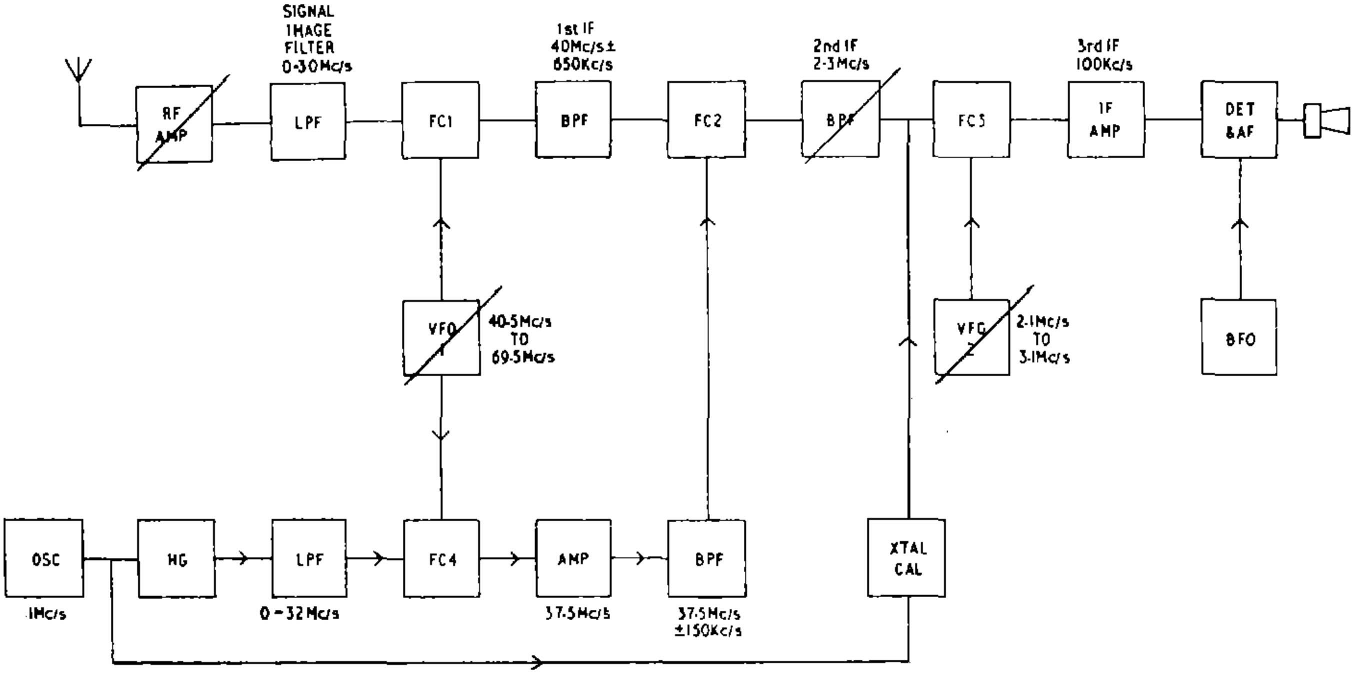

Fig. 5 — Block schematic diagram of special-purpose receiver shown in Fig. 4

The equipment employs thin, endless, flexible belts as the recording medium, stretched taut over two adjacent mandrels, one driven and the other idling. The belts are of cellulose acetate butyrate, five thousandths of an inch thick, and have a peripheral length of twelve inches and a width of three and a half inches. Recording is by lateral swaging, without swarf, at 200 grooves per inch. Belts may be used once only for recording, have a recording duration of eighteen to twenty minutes, and with care may be stored satisfactorily for several years. At least fifty satisfactory playbacks are possible from a recorded belt.

A capacitor run induction motor is used in the recorder, and a similar rather larger motor in the transcriber. The latter is variable in speed ±50 per cent in relation to the fixed speed of the recorder, a wire-wound slider potentiometer being employed for this purpose.

The recorder has an integral four-stage amplifier and is provided with semi-fixed controls for gain and a.v.c. All connections are made via multi-pin miniature connectors, and a jack is provided for checking the input across the recording head. Lamps are provided for mandrel illumination and a valve-operated warning lamp flashes intermittently when the recorder requires attention. Safeguards are provided to prevent mal-operation.

The transcriber has an integral three-stage amplifier and is provided with accessible controls for gain, tone and speed. All connections are made via multi-pin miniature connectors, and one output is available for 600-ohm line connection and is jacked for headphones. The jack is arranged with an insulated micro-switch to connect the mains input to the amplifier, motor and mandrel lamps when the jack plug is inserted. A miniature red lamp, not controlled by the jack plug, indicates the presence of mains voltage at all times.

These machines, with regular and careful maintenance, have in general functioned satisfactorily on an almost continuous twenty-four-hour basis for more than five years.

A few good magnetic tape recorders are employed for special purposes, including the recording of morse signals for later copying. These recorders have alternative tape speeds of 7$\frac{1}{2}$, 3$\frac{3}{4}$, and 1$\frac{7}{8}$ in. per second and can be operated substantially unattended.

5. The Main Listening Room

Forty receiving positions, in five groups of eight, are provided in one large room for monitoring voice transmissions received either by the monitors themselves or, in the case of weak long-distance signals, by engineers at Crowsley. A portion of this room is shown in Fig. 7, in which can be seen monitoring benches and the supervisory console.

Each position is provided with an aerial feed, communications receiver and recorder as already described, and each pair of positions shares an audio switching panel. The latter provides each monitor with a twelve-position rotary switch which, together with tie-lines to a central supervisory console, enables him to listen either to the output of his own receiver or to received signals fed by line from Crowsley. When connected to Crowsley lines an attenuator of 0, 4, and 8 decibels, controlled by a three-position key, is inserted between the output of the rotary switch and the monitor's headphones and recorder connection. The eight recorders of each group are all connected to the console and to each of the eight positions of each group, eight three-position keys, separately available to each position, enabling monitors to select, book or use any free recorder in the group. Lamps above each key indicate at all group positions which recorders are booked

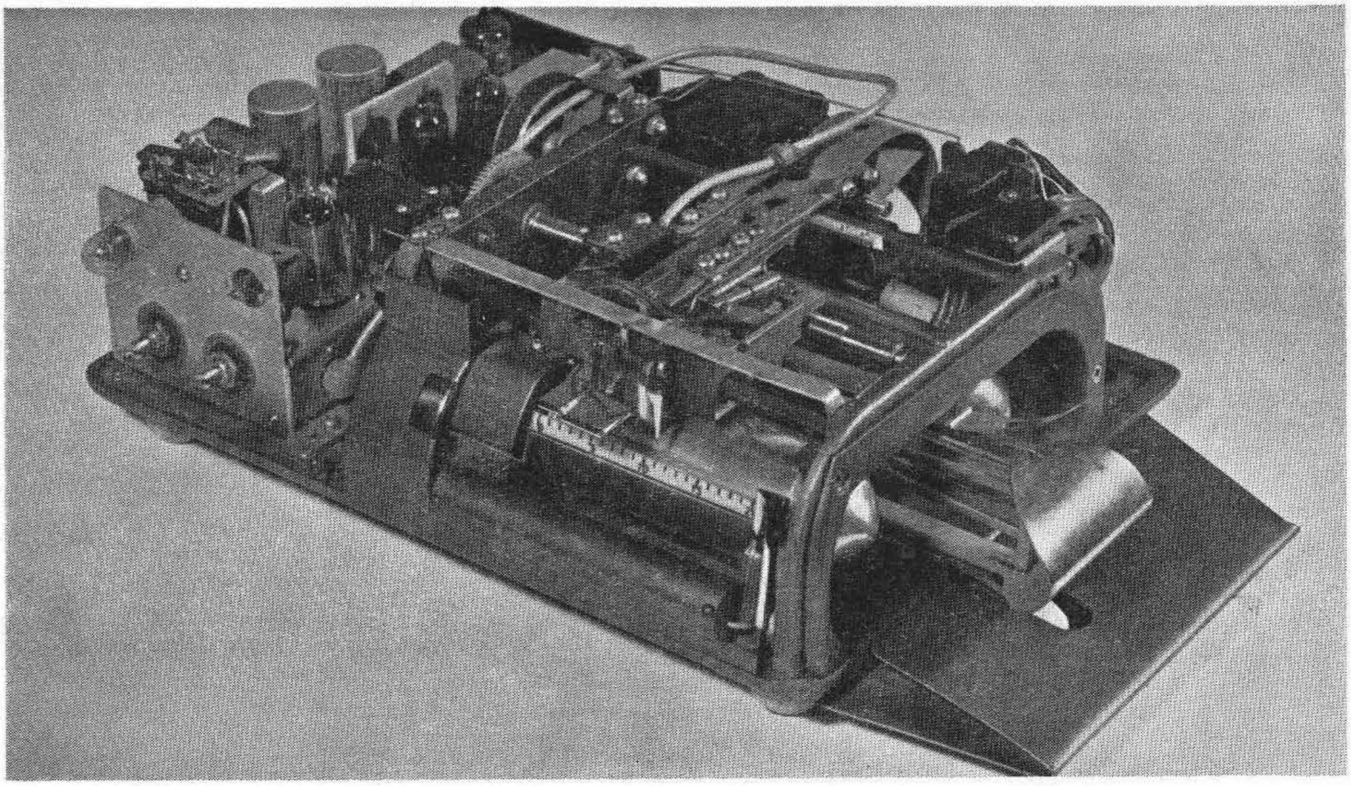

Fig. 6a — Interior of modified recorder used at Caversham

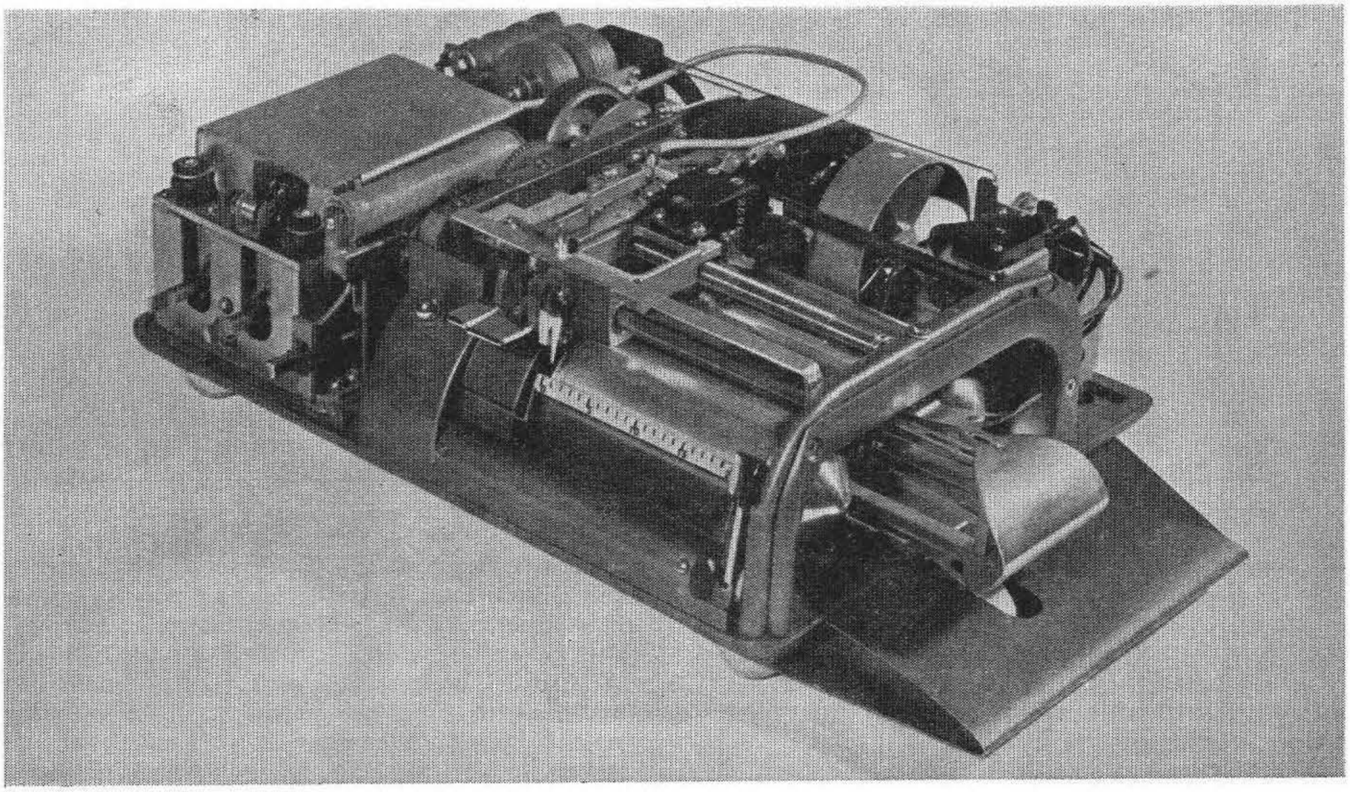

Fig. 6b — Interior of modified transcriber used at Caversham

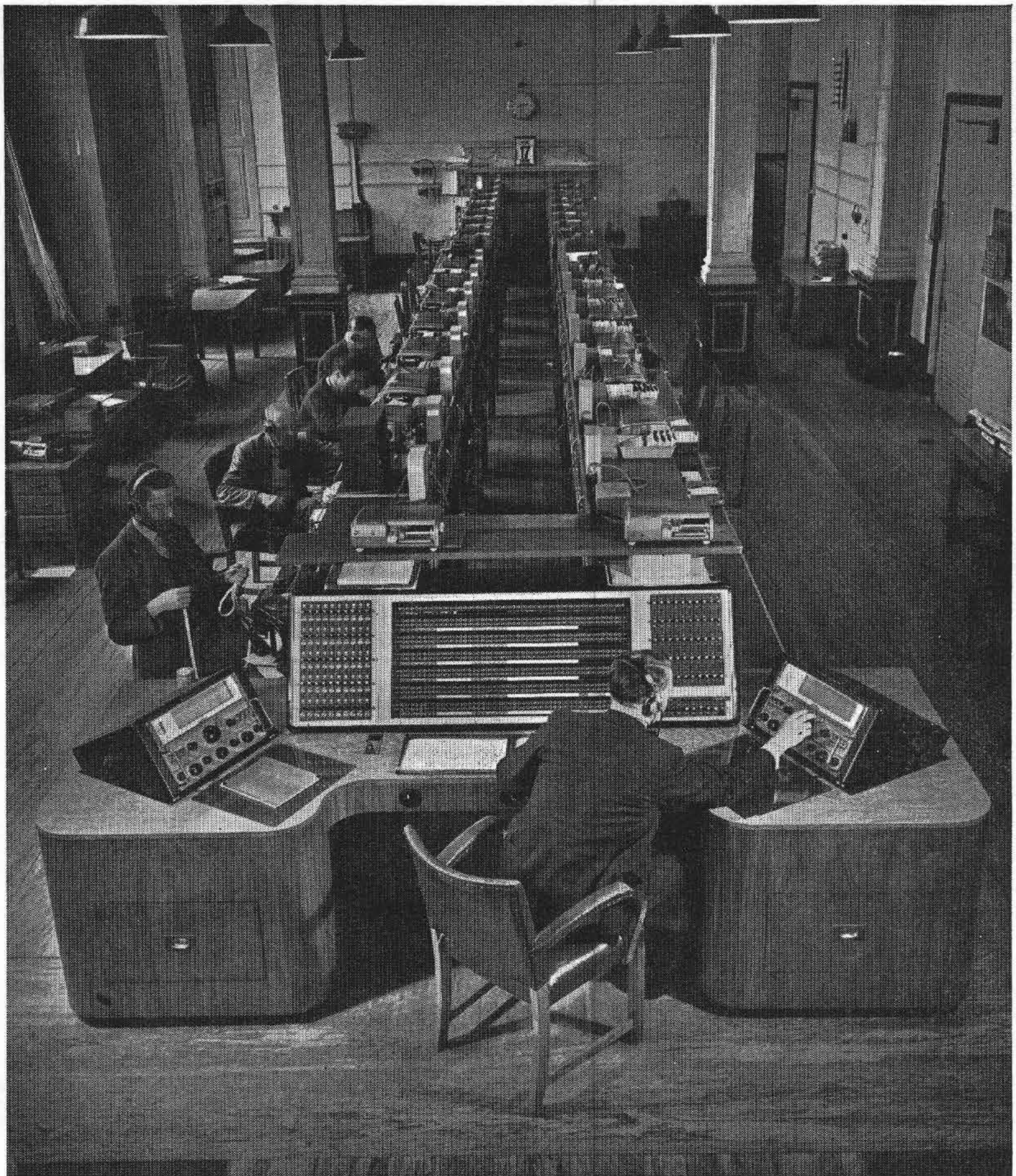

Fig. 7 — Part of the main listening room at Caversham showing monitoring benches and the supervisory console

or in use. A ninth key, connected to the console, is available for connecting a free recorder in any group to any other group. Recorders may be paralleled to provide an overlap when a second recorder is required to extend the recording duration beyond twenty minutes. Microphones, shared between pairs of positions, enable monitors to call, and speak to, the supervisory position.

A few transcribers are used in the listening room, but most are used singly or in pairs in small quiet cubicles.

The console is a master supervisory control desk at which all voice and some hellschreiber circuits are made available on an extensive jackfield and all necessary switching, indicator and alarm facilities, and telephones are provided. The main panel of this console is illustrated in Fig. 8.

The jackfield comprises fifty jacks per row and thirteen rows in all, the latter being allocated in the following sequence starting at the bottom. Rows 1 and 2, line and listen respectively, are for tie-lines to receiving positions. Rows 3 and 4, line and listen, are tie-lines from Crowsley. Rows 5 and 6, line and listen, are the supervisor's own

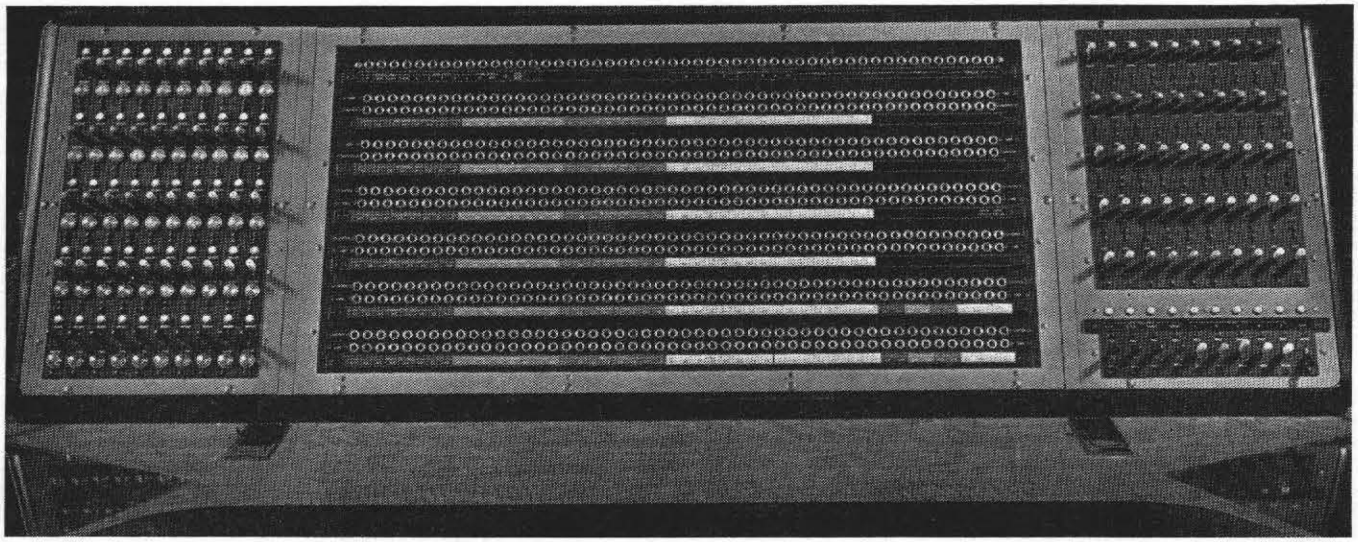

Fig. 8 — The main panel of the supervisory console in the main listening room

'record' key programme inputs. Rows 7 and 8 are line and listen for the monitors' receiver outputs. Rows 9 and 10 are the switching and line connections to 'record select' keys which duplicate at the console those at receiving positions. Rows 11 and 12 are the switching and line connections to the ninth 'record select' key provided at receiving positions, for interchanging recorders between groups. Row 13 is for telephones and other miscellaneous circuits.

The forty 'record select' keys and associate lamps duplicating those at receiving positions are provided as a bank at the left-hand side of the jackfield. Duplicate, flashing, warning lamps of the recorders are also provided at this bank.

A relay switching unit is employed with each recorder to facilitate the above remote operation arrangements.

A further bank of forty three-position keys is provided for checking purposes at the right-hand side of the console. Keys thrown to 'receiver' or 'line' automatically connect the supervisor's headphones accordingly.

Two communications receivers and associate aerial feeds are also provided at the console, and can be seen in Fig. 7.

The facilities described provide good operational control and flexibility at all times and, during the night hours, enable one man at the console to make a substantial number of recordings of signals from Crowsley for transcription during the day.

6. Other Receiving Rooms

Except for two hellschreiber positions in the main listening room, all morse, hellschreiber and radio-teletype services monitored are copied in other rooms, mostly using equipment described in previous sections. Reception of hellschreiber transmissions is carried out in most of these rooms and employs special equipment and facilities.

In the hellschreiber system of transmission characters are transmitted piecemeal by what is in effect a scanning process. In this process the character is regarded as being composed of a series of elements within a blank rectangular frame, the whole forming a mesh of seven vertical and seven horizontal strips, and the character being contained within five of these vertical and horizontal strips. The whole is therefore effectively divided into forty-nine elements and the character composed of selected elements within the central twenty-five. Characters are scanned at a fixed speed from bottom to top and from left to right, and a mark signal is sent each time that an element forming part of a character is traversed.

As an example, if the vertical strips are lettered a, b, c, d, e, f, g, from left to right and the horizontal strips are numbered 1, 2, 3, 4, 5, 6, 7, from bottom to top, then the character 'E' would provide mark signals at b23456, c246, d246, e26, and f26, that is, a total of fifteen mark elements.

Hellschreiber radio transmissions may be simple on-off keyed carrier, frequency-shift keyed carrier, tone-modulated carrier in which the tone is keyed, or tone-modulated carrier in which the resulting carrier and sidebands are keyed.

At the receiving end the demodulated audio-frequency output from the receiver is taken to a thermionic relay unit consisting of a band-pass filter followed by amplifying, rectifying, limiting and d.c. amplifying stages. The output from the latter actuates an electro-magnetic system and causes a knife edge to impinge on the under side of a moving paper tape over which a multiple-start helix is rotating at constant speed. An inking roller, in contact with the helix, produces a film of ink on the helix, which makes ink marks on the paper tape when mark currents cause the knife edge to press the paper tape against the helix. A single variable-speed motor with combined governor and speed control is arranged to drive the helix and paper pull-through rollers, the motor speed being adjustable so that the receiving machine may be adjusted to synchronize approximately with the speed of the transmitter. The receiving machine prints two lines of characters one above the other on the paper tape, and as the transmitter and receiver fall out of synchronism one line of characters becomes divided and meaningless and the other line of characters remains complete. Thus complete synchronism is unnecessary.

The hellschreiber system and equipment are in general very reliable and although barely intelligible characters may be received due to noise or poor radio conditions, erroneous characters cannot result from these causes.

The reception of radio-teletype signals is a relatively recent monitoring activity, and the present arrangements are therefore somewhat fluid. In general, however, long-wave frequency-shift keyed RTT signals are received at Caversham, and the two-tone outputs from receivers connected to frequency-shift adaptors provided with d.c. outputs for direct connection to teleprinters. Similar signals on short waves are, however, subject to fading conditions and these are mostly received in dual diversity at Crowsley using directional aerials, and fed to Caversham as keyed on-off tone. This is connected to a recording bridge which provides a d.c. output for direct connection to a teleprinter.

A balanced modulator at Caversham operating at a carrier frequency of 550 kc/s may be fed with the audio output, at a few kilocycles, of Crowsley receivers adjusted approximately to receive morse or hellschreiber signals. The modulator output at Caversham is directly connected to a receiver there which is tuned to receive either sideband from the modulator. This arrangement gives the monitor at Caversham a means of tuning signals received at Crowsley. In cases where the signal from Crowsley is recorded at Caversham for later copying, the modulator can still be used to give the monitor tuning facilities, but delayed in time.

7. Crowsley Aerials

Aerials at Crowsley are spread over more than two hundred acres of fairly flat land, the greater part of which is let to local farmers. Six single-wire rhombic aerials of the same basic design and dimensions, and one two-wire and eleven single-wire beverage aerials of varying lengths, are directed towards countries from which monitored signals are mainly received. Other aerials available include several long-wire semi-vertical aerials and one pair of Bellini-Tosi crossed loops.

The rhombic aerials are each terminated at the far end in 800-ohm carbon resistances, and at the near end in vertical 800-ohm balanced twin open-wire feeders leading to transformers mounted 6 ft above the ground. These transformers, for 800-ohm balanced to 100-ohm unbalanced connections, are provided with an inter-winding screen and cover all frequencies between 4 Mc/s and 27 Mc/s. They ensure an accurate balance against longitudinal currents picked up by the aerials and vertical feeders, and are also designed to permit d.c. measurements through the transformers to test winding continuity and the value of the aerial terminating resistance. The 100-ohm output from each transformer is connected by buried coaxial cable to the receiving room. Design data for the rhombic aerials are given below:

Height above ground	49 ft
Design wavelength	19·75 m
Angle of elevation, major lobe at design wavelength	17°
Major axis	596 ft
Minor axis	182 ft
Length of side	311 ft
Side angle	146°

Rhombic aerials based on this design give an angle of elevation for the major lobe of 11·9° at 14 m, and 35° at 49 m.

The beverage aerials vary between 900 and 3 000 ft in length, are supported every 150 ft on poles at a height of 10 ft, and are connected directly to the receiving room via an aerial gantry. These aerials are terminated at the far end in 500-ohm carbon resistances, and at the receiver room in an unbalanced 500-ohm to unbalanced 100-ohm autotransformer covering all frequencies between 100 kc/s and 27 Mc/s. The latter are connected to the aerial distribution bays via 100-ohm flexible coaxial cable.

The single two-wire beverage aerial is provided with a reflection transformer and two output transformers, the latter both located close to the receiving room. One of these outputs has a uni-directional performance in one direction and the other a similar performance in the opposite direction.

The semi-vertical aerials are slung from triatics between four 100-ft tubular steel, stayed masts arranged to form a square of 220-ft sides.

The Bellini-Tosi crossed loops are used primarily for rejecting unwanted signals. They are 30 ft in height and connected through buried and equalized lengths of screened twin balanced cable to the receiver room.

All aerials except the loops are provided with lightning arrestors, those for the verticals and beverages being positioned at the point of entry to the receiver room. Those for the rhombics, and twin fuses, are provided at the aerial transformer in the field.

A buried earth mat is provided close to the receiver building for earthing all receiving equipment.

8. Crowsley Aerial Distribution

Some octave amplifiers similar to those at Caversham are used as required to enable aerials to feed a number of receivers. Resistance-coupled distribution networks are used to divide the single outputs of these amplifiers into eight separate outputs.

Another form of amplifier is also used, consisting of a push-pull stage driving ten push-pull stages through low-pass filter networks. This amplifier shown in Fig. 9 covers all frequencies between 100 kc/s and 27 Mc/s, and is provided with negative feedback decreasing with increasing frequency. The single input and ten outputs of the amplifier are suitable for connection to 100-ohm coaxial circuits. The operational advantage of these amplifiers compared with the octave amplifiers is that all ten outputs from the former cover most frequencies in use at Crowsley.

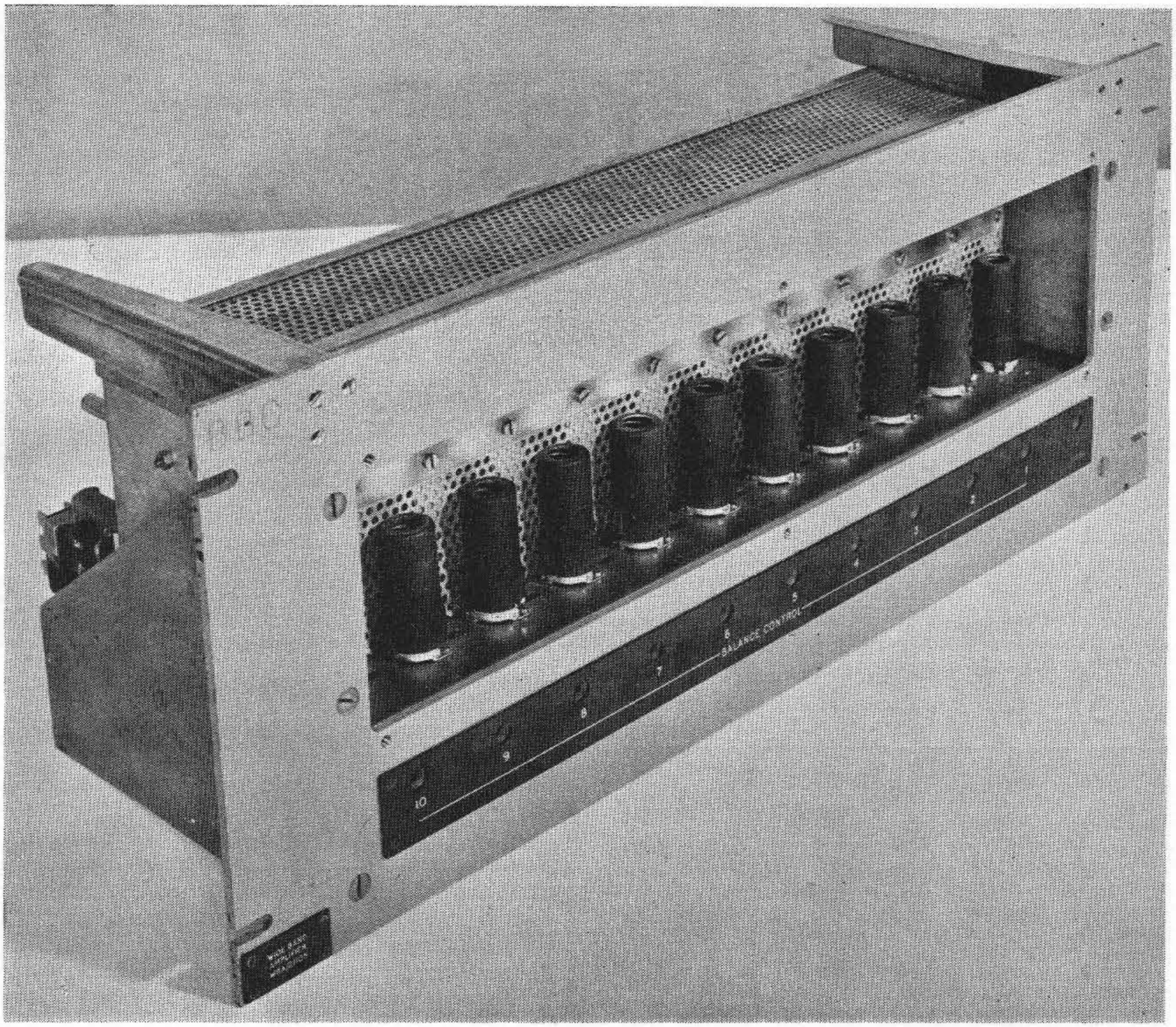

Fig. 9 — Special wide-band aerial amplifier

All aerials and all of the inputs and distributed outputs of all aerial amplifiers are taken to a central field of two hundred and forty musa coaxial sockets, shown in Fig. 10. Two aerial connections from the field are taken to each receiver, and terminated on a two-position switch to enable receivers to be provided with two aerials and the best selected at any time. All receivers are also provided with switchable aerial attenuators. Most aerial amplifiers are located close to the field but some are placed elsewhere due to lack of space.

9. Crowsley Receivers

Thirty of the single-superheterodyne receivers already described in Section 3.1 are rack mounted and used to feed voice, morse and hellschreiber signals to Caversham. The receivers are operated substantially by one engineer. A number of the receiver racks is shown in Fig. 10.

All receivers are connected to Caversham in a multi-pair telephone cable which also carries telephones. Receiver racks are all provided with jacking and switching facilities and tie-lines to a line termination jackfield.

All thirty receivers are provided with associate crystal-controlled oscillators with six switched crystal positions, two of the crystals being in small temperature-controlled ovens. These are very useful in cases where regularly monitored transmissions keep fairly rigidly to frequency and do not change too often. These restrictions are met only infrequently at Crowsley and at any time only a small proportion of the available crystals can be used.

10. Crowsley Auxiliary Equipment

A small control position is provided at the centre of the receiving room and is provided with aerial feeds, a receiver, and rapid checking facilities covering all signals fed to line. Telephones and loudspeakers are also located at this position.

Two frequency measurement equipments are provided for confirmation of received frequencies. One is fairly

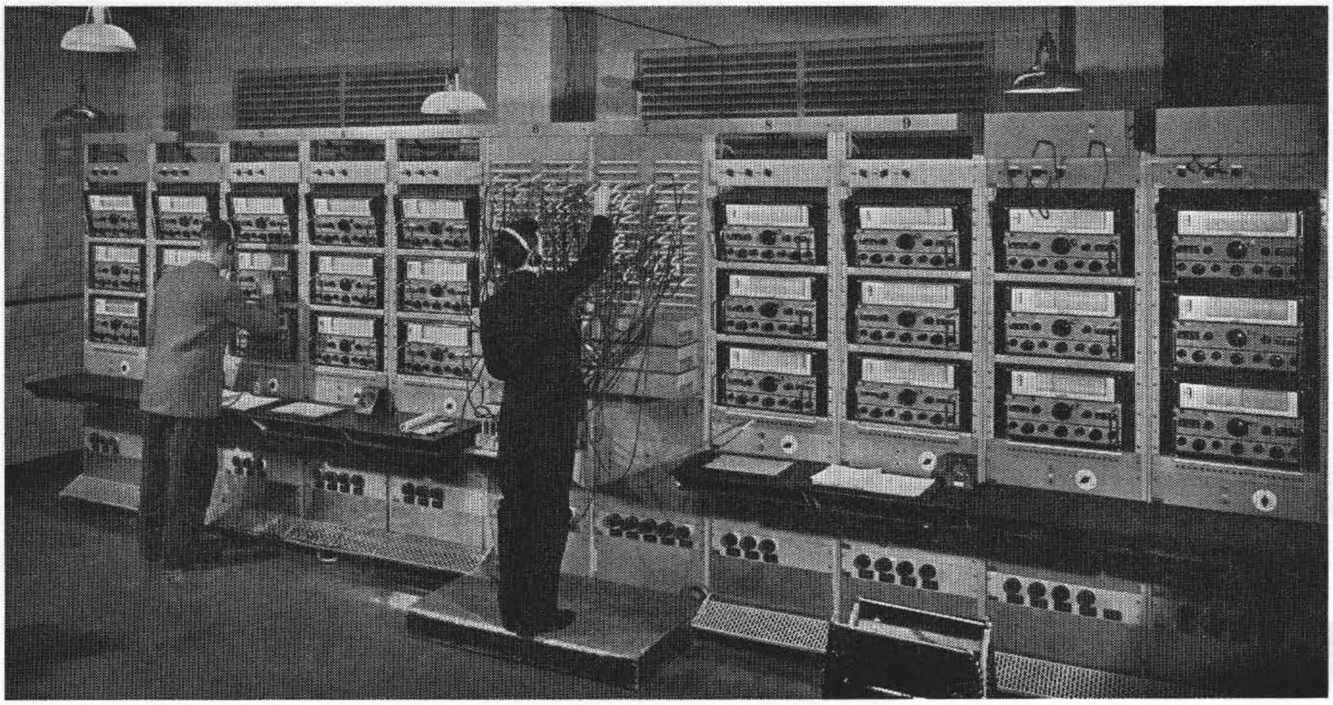

Fig. 10 — Part of the main receiving bays and aerial distribution panel at Crowsley

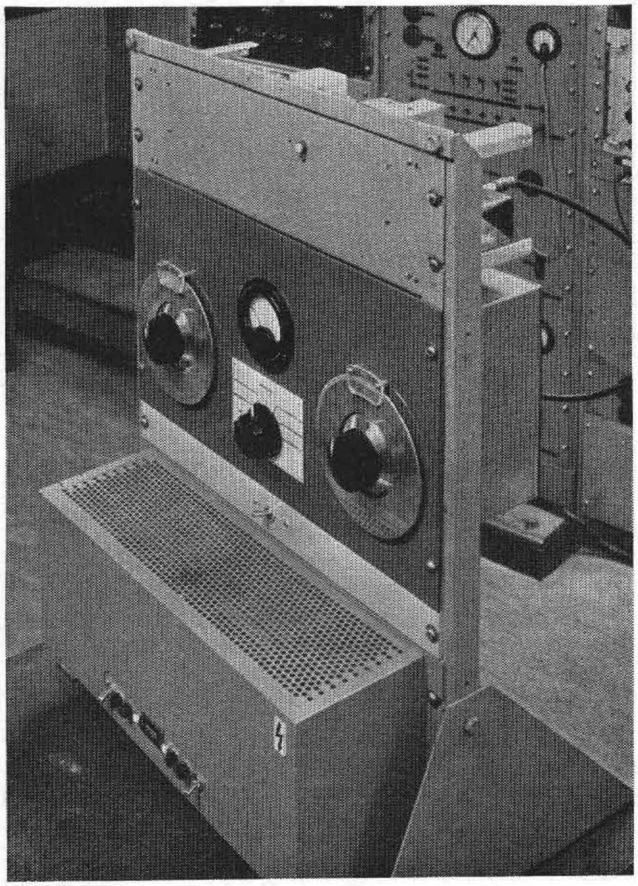

Fig. 11 — Crystal-controlled frequency measuring equipment

standard, covers low, medium and high frequencies, and comprises a crystal-controlled master oscillator in a thermostatically controlled oven, a series of multivibrators, two interpolating oscillators and a detector amplifier. The second is based upon the principles employed in the oscillator arrangements of the unconventional receiver already described in Section 3.3. The latter equipment, shown in Fig. 11, is of South African design and manufacture, and has a frequency range of 2 Mc/s to 7 Mc/s. A crystal-controlled 100-kc/s master oscillator of British design and manufacture is employed with this equipment, and a very simple harmonic generator is provided to extend its high frequency range above 7 Mc/s.

Very low frequency convertors already described in Section 2.3 are available for use at Crowsley, and other equipment of general application includes low-pass, high-pass and band-pass audio-frequency filters, audio-frequency amplifiers, an audio-frequency oscillator, and all test equipment for maintenance purposes.

Several radio-teletype positions, each operating in diversity, employ two receivers, each crystal controlled. For the reception of frequency-shift keyed signals the two-tone outputs from each of these receivers are centred on 2 500 c/s and connected to a diversity switching unit operated by the receiver a.v.c. voltages. The single two-tone output from this unit is connected to a frequency shift adaptor, the output of which is a keyed 2000-c/s tone. This is fed by line to Caversham and operates teleprinters as already described. Checking facilities at Crowsley include a small general-purpose oscilloscope for checking the waveform sent to line, and one tape teleprinter covering all positions, for printing at Crowsley when required. A siphon-pen undulator is also available.

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