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A record of BBC technical experience and developments in radio and television broadcasting

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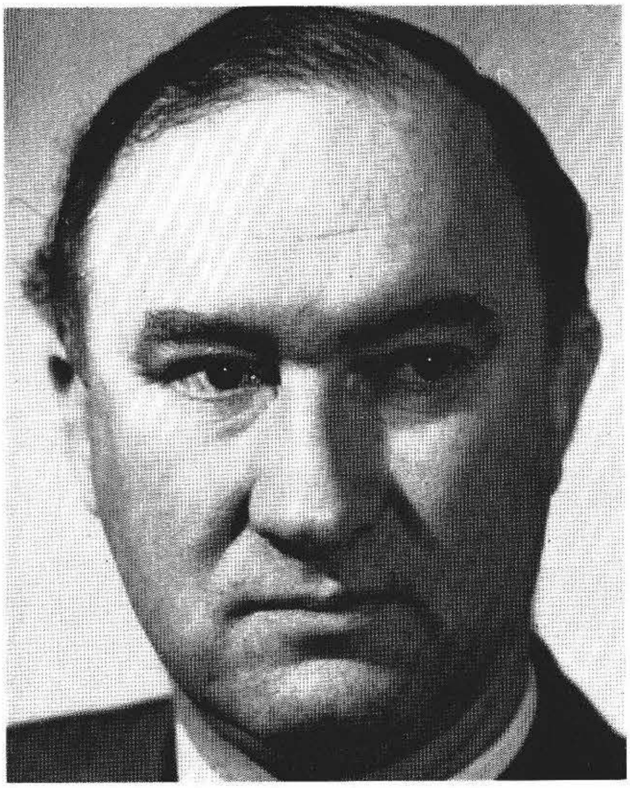
Foreword

by the Director-General, British Broadcasting Corporation



The BBC, as one of the world's largest broadcasting organisations, offering programmes in radio and television to audiences in Britain and overseas, and seeking to satisfy the triple injunction of providing information, education and entertainment on a mass scale, has a unique diversity of responsibilities. It might be thought that this diversity of occupation might tend to produce within the BBC a series of separate introspective groups each concerned more with its own functions than with those of others in the same organisation. But for those who serve in the BBC for any length of time the overriding sense is one of unity and of great cohesion between the parts. This is partly the result of long tradition and continuity of evolution, but it also reflects in part the existence of many departments whose work extends across the whole spectrum of BBC activities – personnel, finance, and engineering being the most obvious. The BBC's Engineering Division – as it was originally called, and as it has traditionally survived, though the word 'division' is no longer in common use as a BBC organisational description – was really the genesis of all broadcasting in this country. Every part of the BBC calls on the services of engineers – for everything from the esoteric mysteries of electronics to the normal complexities of building and maintaining accommodation. The professional skills of all the BBC Engineers are essential to the successful conduct of the broadcasting operation. They have never failed in enthusiasm when faced with the demands of the programme production departments for ever-expanding technical facilities. This process of continuous development, both in personal skills and professional technique, has kept the BBC in the forefront of broadcast technology. But it has also had a unifying effect which has been of the utmost value to the BBC as an institution.

I am glad to have this opportunity of expressing my appreciation of the work of the Engineering Division in the 50th Anniversary issue of *BBC Engineering*.

Editorial

Broadcasting, Communication and Mobility

In this fiftieth anniversary year of the BBC, we may consider how broadcast engineering is likely to be affected by changes in our general way of life which may well come about during the next decade or so. There is at present a very vocal and influential body of opinion who take the view that the motor car should be largely abolished in the interests of conservation of the environment. Some of the more clear-thinking supporters of this line of thought have acknowledged that public transport can never match the mobility offered by private cars, and have accordingly suggested that personal mobility should no longer be regarded as a primary objective in national planning, priority being given to other forms of communication not involving transport. With or without this priority, and whatever the fate of the motor car, there will be a greatly increased emphasis on the development of both existing and new forms of broadcasting.

At present, about 95 per cent of homes have television (licensed or otherwise), and practically everyone with some measure of hearing listens to the radio at times, so there is only limited scope for bringing broadcasting into homes which do not yet have it. But one wonders whether Britain—especially a car-less and immobile Britain – will remain content with a mere three television and four or five radio channels. There is likely to be a massive increase in the demand for additional broadcasting channels and for other forms of instant communication which reach directly into individual homes. Pressure for a fourth u.h.f. television channel will be hard for the government of the day to resist, as will the demand for liberation of the v.h.f. spectrum from 97·6 to 108 MHz (allocated to broadcasting as long ago as the Atlantic City Conference of 1947) and the u.h.f. Band V from 854 to 960 MHz. Cable television will gain greatly increased impetus, either on its own or as part of the facilities provided by a national wideband cable (or even optoelectronic) information distribution network. If wired or wave-guided television becomes available as a means for enabling the viewer to call up a recorded programme of his own choice, the broadcaster may find it expedient to change his programming policy by concentrating more on live items. Direct broadcasting from geo-stationary satellites, on a super-high frequency around 12 GHz, will almost certainly be brought into use. Not only can this make at least four additional nationwide television channels available: it can provide coverage for nearly all of the people living in those areas which will not be covered even when the currently-planned u.h.f. network is complete. Although these people total only 1 per cent to 3 per cent of the population (according to one's definition of 'coverage'), they deserve special consideration because most of them live in remote areas lacking other forms of entertainment and recreation. If deprived of the use of cars their need for other forms of communication will be even greater. As u.h.f. and s.h.f. viewing spread, legislation may be needed to help would-be viewers who are on the 'wrong' side of the building in which they live and cannot mount an aerial directed at the transmitter. Landlords (either council or private) who object to the erection of an aerial on the roof of the building in such circumstances may have to be overruled. Another problem of u.h.f. and s.h.f. reception which may need a legal remedy is that of people whose reception is adversely affected by new buildings obstructing the path from the transmitter to their aerials. Some legal provision analogous to the concept of 'Ancient Lights' may be needed, but it is not for us to say whether this will be known as 'Ancient Millivolts'.

A new system known as Ceefax, which the BBC has devised and expects to demonstrate next year, will exploit hitherto-unused time slots in the blanking periods of the normal television signal for transmitting digitally-coded signals. These are already being used by the broadcaster to convey a high-quality sound signal without using a separate sound channel, as well as for quality control and monitoring, and the technique is to be extended to provide a new source of information for the viewer. The coded information will be stored in the television set and continuously updated, and by pressing a button to interrogate the store, the viewer will have the latest news summary, sports results, weather forecast, etc. displayed in writing on his television screen. In a literate society (assuming that we continue to merit this description) written information will always remain an essential complement to the spoken word or transient pictures.

Broadcasting is one of the few activities which has not been condemned by conservationists as damaging to the environment. If reduced personal mobility is to be imposed on us in the name of conservation, the broadcaster will come into his own as he never has before.

The First Five Years

An Account of Some of the Early Installations and Activities of the BBC

Peter West, M.A. (Cantab.)
Formerly Head of Engineering, West Region

1 The Three Original Stations

The BBC took over responsibility for broadcasting on 14 November 1922. It had no studios, no transmitters, not a single piece of equipment to call its own, and no staff either for that matter. So, perforce, it started in business by taking under its wing three of the four broadcasting stations that had been set up by the big electrical firms.

These three* stations were 2LO in London, 5IT (originally

* The fourth was 2MT, Writtle, which continued to be run by the Marconi Company.

Fig. 1 The original studio of 5IT Birmingham. It had a floor area of just over 300 sq. ft. *G.E.C*

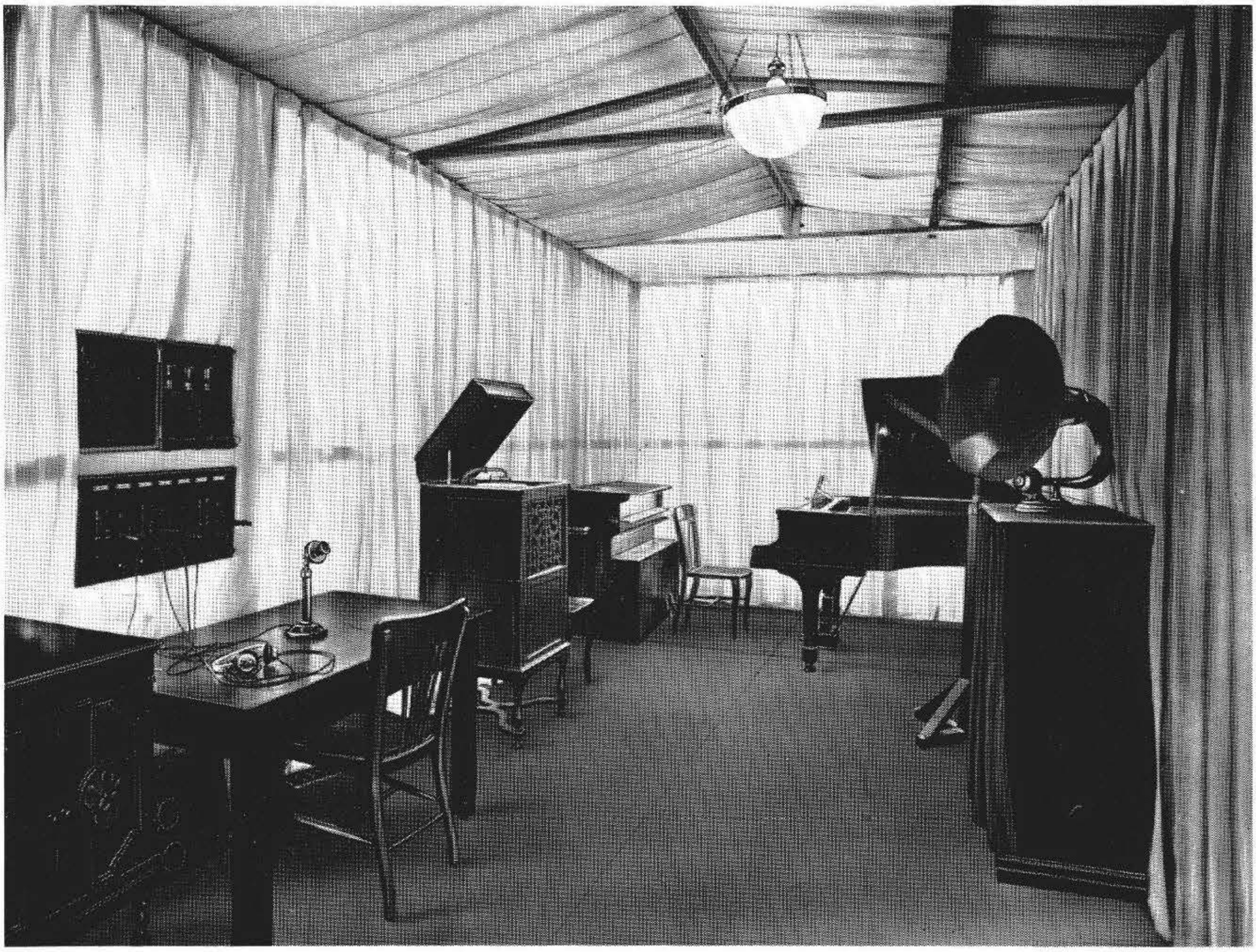


Fig. 2 Manchester's first studio. 'The walls and ceiling were swathed in draperies to smother the slightest echo.' *G.E.C./A.E.I.*

2WP) in Birmingham, and 2ZY in Manchester. They were pretty modest installations, consisting of a studio, or concert room as it was still called at 2LO, and a low-power transmitter. The studios (Figs. 1 and 2) and were much alike; small, with their floors thickly carpeted and their walls and ceilings swathed in draperies to smother the slightest echo. The 2LO studio, for example, was draped with thin white muslin, which soon became dingy in the sooty London air – 'Only three years ago,' recalled Peter Eckersley, the BBC's first Chief Engineer, writing in *Popular Wireless*, 'the main studio of the London broadcasting station was hung with dirty mosquito netting.'

The equipment, by contrast, had little in common, since each station had been created by a different firm. 2LO, in the Strand, belonged to the Marconi Company and had been broadcasting regularly since 11 May 1922. The BBC assumed responsibility for it on 14 November. 2WP (Fig. 3) was a Western Electric venture. Originally located in London, just off the Strand in Norfolk Street, it had been hastily dismantled on 10 November and shifted, in steam lorries, to the General Electric Company's works at Witton, where it arrived on 12 November. A small army of painters, carpenters, and wiremen moved in, and by 4 o'clock on Wednesday, 15 November, all was ready. After an hour's preliminary testing broadcasting began at 5 o'clock. A few days later the call-sign was changed to 5IT. The third station, 2ZY (Fig. 4), was sponsored jointly by the Metropolitan-Vickers and Radio Communication companies. Located at Trafford Park, it had started regular experimental broadcasts the previous May. As in Birmingham, official broadcasting under the aegis of the BBC started on 15 November.

2 The Main Stations

Within a year five more stations had been built and commissioned, bringing the total up to eight. The first to be completed was Newcastle, which opened on 24 December 1922 in time, but only just, to honour a promise that transmissions would start before Christmas. Even so, when the day came, the studio in Eldon Square was not quite ready, and the first broadcasts had to be done from a lorry drawn up in the yard of the Co-operative Stores in Blandford Street, where the transmitter was housed. Two more stations, Cardiff and Glasgow, followed in March 1923, and a further two, Aberdeen and Bournemouth, in October. One more station, Belfast, was added a year later, in October 1924, making a total of nine main stations, as they were subsequently called.

Each of these later stations, from Newcastle onwards, was equipped with a Marconi Q transmitter, a direct descendant of the transmitter that had been gradually built up during

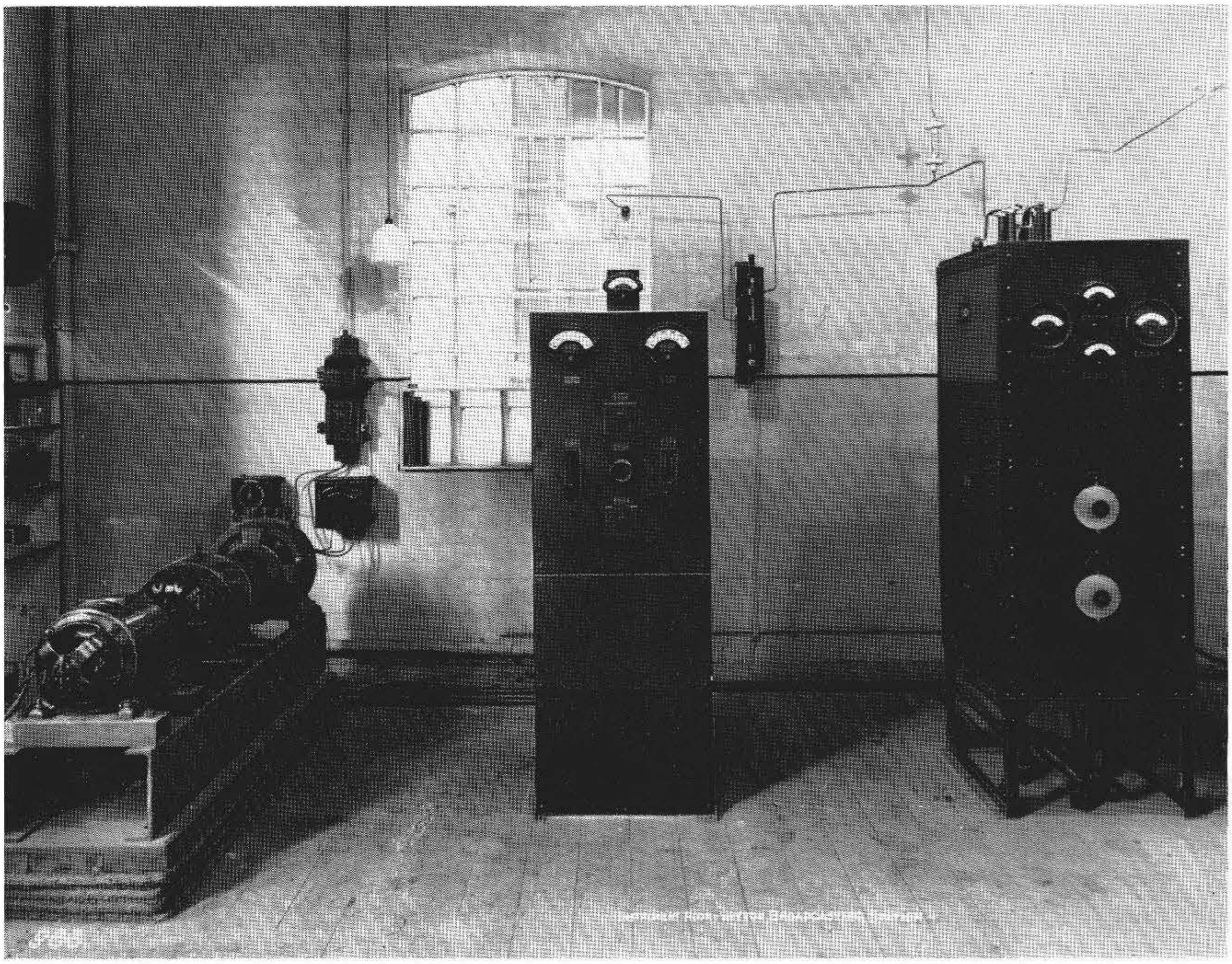


Fig. 3 5IT (originally 2WP) Birmingham, the 'instrument' room at Witton. The Western Electric transmitter (right) was rated at 500W r.f. output. Note the pile of doormats under the motor-generator set. *G.E.C.*

1922 for the 2LO station at Marconi House. These Q sets were variously rated at 6kW – the power drawn from the mains supply – or 1·5kW, which was the power input to the final stage. The r.f. output to the aerial was about 1kW.

In contrast to the original London, Birmingham, and Manchester stations, the studios and transmitters for the later stations were not in the same building, but were separated from one another by anything up to two or three miles. For the transmitter the aim was to find a site reasonably near the centre of the service area, unobstructed by buildings or hills, preferably with at least one high anchorage for the aerial (Fig. 5). Not surprisingly, power stations, with their lofty chimneys, were a popular choice. By 1924 they were housing no less than five of the nine main transmitters. Of the remaining four, only two – Aberdeen and Bournemouth—had their aerials out in the open, slung from 110ft masts rather than from buildings or chimneys, and at only one, Bournemouth, was the land owned by the BBC with a tailor-made building on it for the transmitter.

As broadcasting became more ambitious the original stations soon outgrew their very modest premises. 2LO was the first to make a move, with the opening of Savoy Hill in May 1923, though the transmitter stayed on at Marconi House for the time being. 5IT and 2ZY both found new homes in August 1923, 5IT above the New Street picture house in Birmingham, where Sir Herbert Austin opened a new studio, 20ft square, on 11 August. *Popular Wireless* approved. 'Being so conveniently situated,' it declared, 'it will offer great facilities for the engagement of artistes and also the transmission of the various productions at the theatres and other places of amusement.' The Western Electric transmitter was removed from Witton and installed in the Summer Lane power station, about half a mile from New Street, with a sausage aerial slung between the two chimneys. This move was accomplished in less than twenty hours, with no loss of transmission.

Within two and a half years New Street, in turn, had become hopelessly inadequate. So, at the beginning of 1926 yet another move took place, this time to a brand new building opposite the Prince of Wales Theatre in Broad Street. From then on for several years Birmingham was the proud possessor of the finest headquarters in the provinces, with two studios, one of which was the largest in the country – bigger even than the biggest studio in London. A few months earlier, in September 1925, a more powerful Western Electric transmitter, with an output of 1kW, was installed at the Summer Lane power station, thus bringing Birmingham into line with the other main stations.

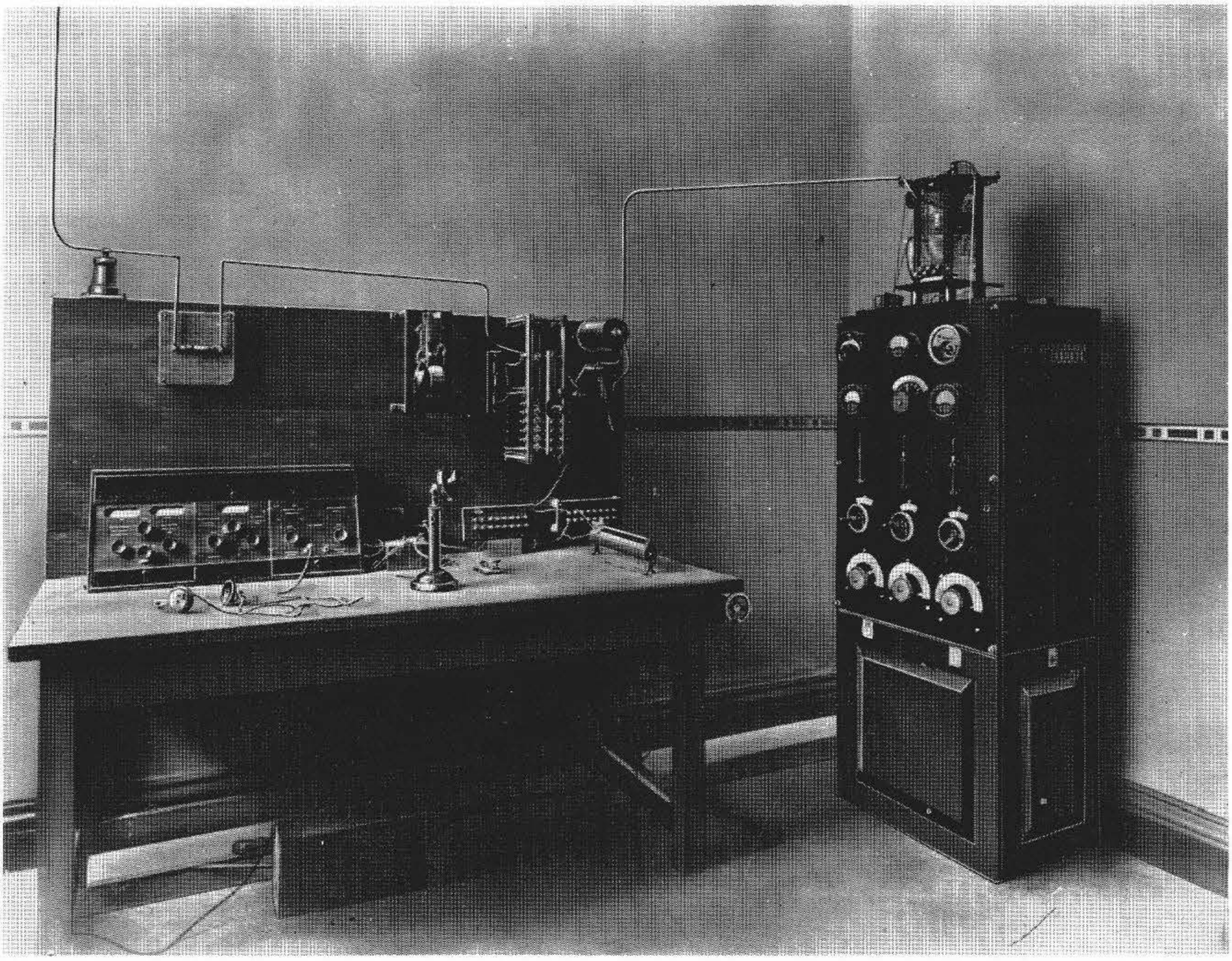


Fig. 4 The original Radio Communication Company 2ZY Manchester transmitter (right) at Trafford Park. It was rated at 800 W input to the final stage. *G.E.C./A.E.I.*

In Manchester events followed much the same pattern. On 3 August a more spacious studio, 30ft × 14ft, was opened on the fourth floor of a cotton warehouse in Dickenson Street. Reached by a goods hoist which the occupant had to heave up and down himself, this must have been a remarkably inconvenient place. Its only redeeming feature was that the transmitting aerial could be strung directly out of a window up to a chimney of the Corporation's power station alongside.

Not altogether surprisingly, the Dickenson Street premises did not last long, being superseded on 12 December 1924 by new quarters in Orme Buildings, The Parsonage. There was much more elbow room, with two studios, in Orme Buildings, but it was not, seemingly, a very salubrious position – three floors below street level overlooking the River Irwell. *Popular Wireless* commented, somewhat oddly: 'Through the heart of Manchester flows the River Irwell, a narrow thread of dark, evil-looking water, seeming to bear with it all the light refuse of that multitude of factories which line its sinuous course. And on the eastern bank of this canalised waterway, immediately opposite a gaunt, drab cotton mill, are situated, appropriately enough, the headquarters and studios of the Manchester broadcasting station.'

Of the other main stations, Newcastle celebrated its third anniversary by moving into much more spacious quarters in

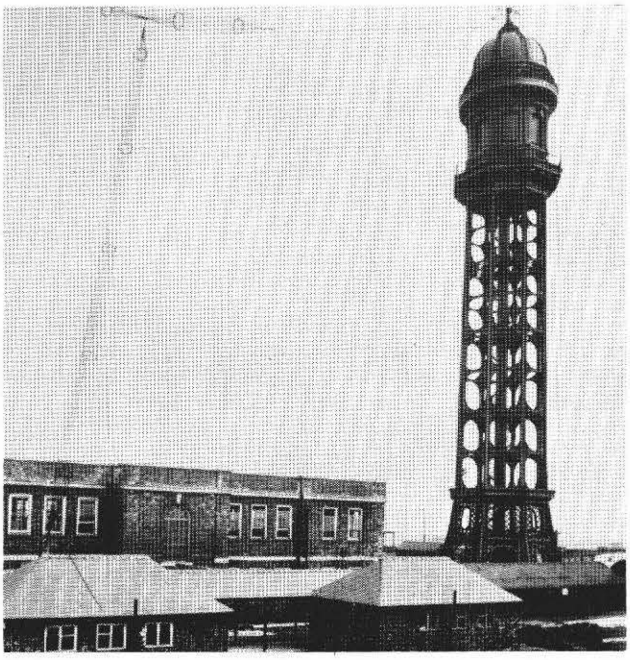


Fig. 5 Transmitting aerial, supported by water tower, for 2ZY Manchester at the Metropolitan-Vickers works, Trafford Park. *G.E.C./A.E.I.*

New Bridge Street. *Radio Times* reported: 'An extensive suite of offices constitute the ground floor, whilst above is the Studio, which is approximately 40ft square, formerly comprising eight rooms. There is also a smaller studio for talks, an artists' waiting room etc., and everything is on a most up-to-date plan . . . in fact, the "new home" is most artistic throughout, and the change from Eldon Square, where the work in the past has been carried on under great handicaps, will be generally appreciated.'

Cardiff and Glasgow, likewise, moved into more spacious quarters in May and November 1924 respectively. Cardiff set up at 39 Park Place, initially with one studio, but in February 1926 the premises were enlarged and a second studio, for talks, was added. Glasgow achieved two-studio status earlier, on their move to a handsome stone-built house in Blythswood Square in November 1924.

To begin with the BBC, having more pressing problems on its plate, took the line of least resistance and went on using the 2LO transmitter at Marconi House. It was not, however, an ideal arrangement. In the words of Adrian Simpson, deputy managing director of Marconi's, 'I appreciate that until you get the new London station going you are handicapped owing to the station being installed at Marconi House where you cannot do all that you would like. We also feel the handicap as it is objectionable to have bands of strangers coming in and out and to have Engineers of other Companies working amongst certain of our experimental gear, and moreover the present installation is by no means a show-piece or as safe as one would like.' Apart from these drawbacks the 2LO transmitter was causing interference to the Air Ministry's station in Kingsway, and as a result there was pressure from that quarter for the BBC to go elsewhere.

Prospecting for another site started at the end of December 1922. The first to be suggested, by R. H. White of the Marconi Company, was the Institution of Electrical Engineers building in Savoy Place with an aerial between 100ft masts on the roof or extended over to another mast on the roof of the Savoy hotel next door. Other possibilities that were looked into were Harrods in Knightsbridge, Waterloo station, Boots' warehouse, the telephone exchange in Tottenham Court Road, Shaw & Kilburn's building in Wardour Street, where a roof-top site was actually secured but had to be turned down in the end because of insufficient security of tenure, and Selfridges in Oxford Street. The choice was a pretty restricted one, in view of the stipulation by the Air Ministry and Admiralty that the transmitter must be at least a mile from their installations in Kingsway and Whitehall, and the need to keep within a mile and a half of the studio, and north of the Thames, because of the limitations of Post Office lines at that time.

In the end Selfridges proved to be by far the best site on every count. An agreement was signed in July 1924, under which the BBC was to pay Selfridges 'an annual sum of Ten Shillings (if demanded) by way of rent'. For their part, Selfridges were expressly prohibited from deriving any publicity from the presence of the BBC's station on their premises. Two 125ft towers were erected on the roof for the aerial and a couple of huts for the transmitter and power equipment. A Marconi double Q transmitter, rated at 12kW input – double the power of the Marconi House transmitter – took over the service on 6 April 1925. The Marconi House transmitter, however, was retained as a stand-by. In 1929, to his eternal credit, Sir Noel Ashbridge arranged for its preservation, and it must now be one of the earliest broadcasting transmitters in existence, if not the earliest.

The decision to go to Selfridges excited some suspicion and hostility when it was first revealed. This was subsequently aggravated by a report in *Amateur Wireless* that the BBC hut on the roof would have large windows, so that the public would be able to see the transmitting apparatus without interfering with the running of the station. 'What is the objection', inquired the *Wireless World*, 'in view of the increasing wealth of the Company, to the BBC being the owners of the site on which the new station is to be created. It would seem that such an arrangement would be more satisfactory from all points of view, more especially, we should imagine, from the point of view of the Company itself, as it would short-circuit any criticism that it was favouring the interests of any particular commercial concern.' And in the House of Commons Mr Baker asked the Postmaster General whether the removal of 2LO from Marconi House had been designed to advertise the firm owning the leading West End store to which it was going; what value was placed upon the advertising value of the presence of the transmitting station, and whether the sum so paid would be transferred to the revenue of the Broadcasting Company? He received a reassuring reply.

3 The Relay Stations

'The year 1923 saw the erection of the main stations; 1924 will always be thought of as the relay station year,' wrote Eckersley in the *Radio Times* at the end of 1924. And so, indeed, it was. Ten stations were completed that year, starting with Plymouth in March, and ending with Swansea in December.

By the end of 1923 it was reckoned that twenty-two million people were within thirty miles of one or other of the BBC's stations, and hence within reception range. But this meant that another twenty-two million – half the population – were still without a proper service. Clearly something had to be done for these people. High-power stations were not yet a reality. The cost of building more 6-kW main stations would have been too high and would have created interference problems, because there were not enough wavelengths to go round. It was therefore decided to go ahead with low-power relay stations in the more thickly populated areas.

The first tentative step was taken in May 1923 when Eckersley went to Sheffield to see for himself what grounds there really were for the complaints of poor reception. As a result of his visit an experimental station was set-up in August under the auspices of Sheffield University on their premises. There were difficulties, however, and after a few days the station was shifted to the house of Mr F. Lloyd, the President of the Sheffield Wireless Society. The transmitter was installed in his garage, and the drawing-room was transformed into a studio by draping it with army blankets to deaden the echo. Regular musical programmes were broadcast on Mondays and Thursdays at 8 p.m., and a talk on Sunday evenings. Crystal-set reception as far out as Doncaster, twenty miles away, was achieved.

The experiment was successful enough for the BBC to put the Sheffield relay station on a proper footing. In November 1923 it was transferred to the second floor of Union Grinding

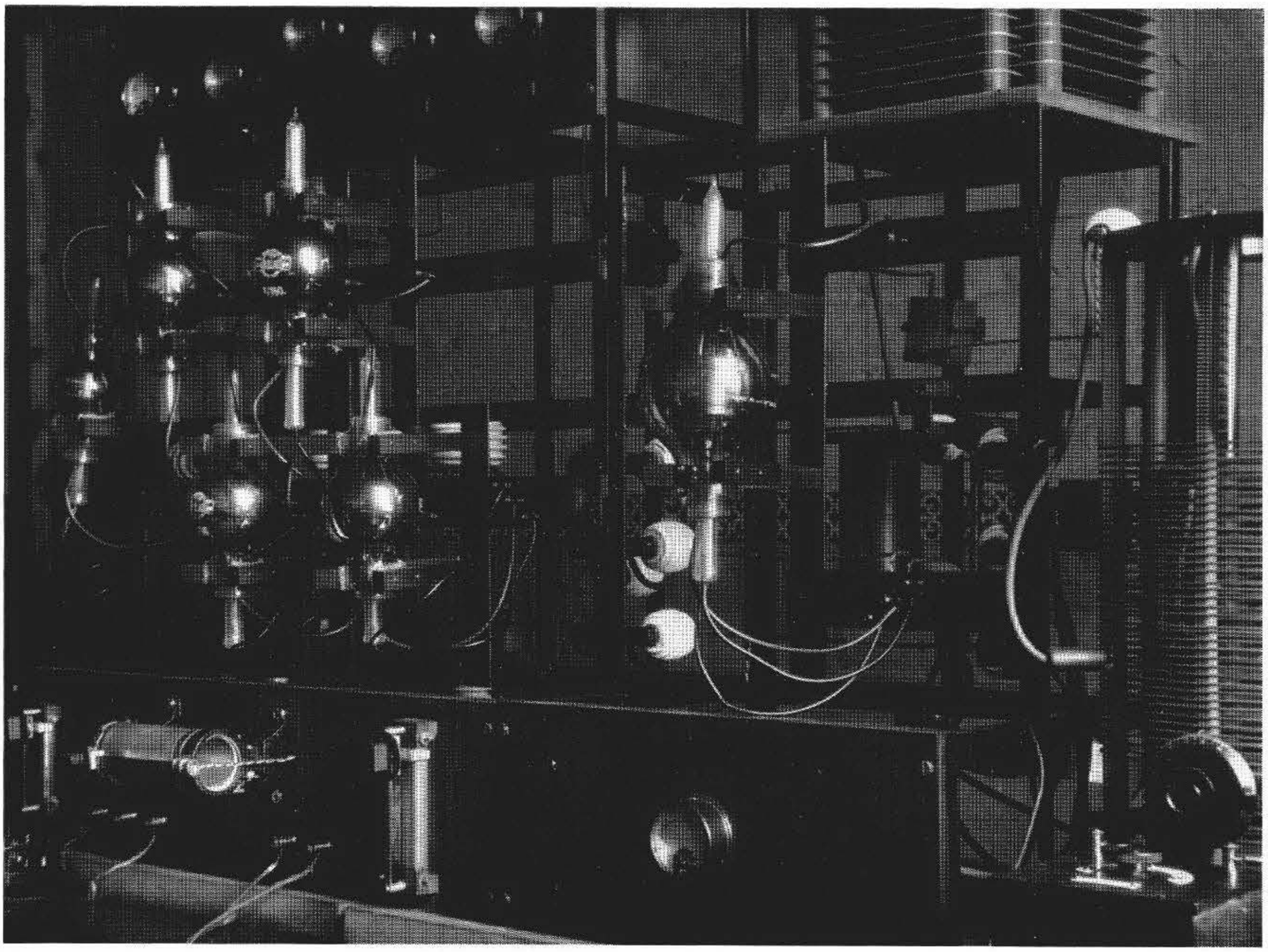


Fig. 6 Standard BBC-designed 200-watt relay transmitter. Left to right: Sub-modulator and modulator (with four valves in parallel), choke-modulated self-oscillator, tuning unit. *Chris Hodgson*

Wheel, a cutlery manufactory in Corporation Street. Here a small studio, tastefully fitted up in panelled black and white, according to *Popular Wireless*, and a 100-watt transmitter with its aerial anchored to a nearby chimney, were accommodated. Programme was taken by line, initially from Manchester, but later on from Birmingham. Additionally, a receiving station was set up at Greenhill, just outside Sheffield, for rebroadcast reception, in case of line trouble, but this seems not to have been very successful.

Sheffield had the distinction of being not only the pioneer relay station but also the only BBC station with any claim to literary associations. Charles Reade, in his novel, *Put Yourself in His Place*, describes several events that took place near Union Grinding Wheel during the 'rattening' period of Sheffield's history, when there was a reign of terror in the city.

Early on in 1924 the BBC's Development section devised a standard relay-station outfit. H. S. Walker, a well-known radio amateur whom the BBC had taken on in 1923, was the engineer chiefly responsible for the design. It was a pretty simple affair. The transmitter consisted of a couple of angle-iron frameworks for the self-oscillator and modulator, a tuning assembly, and a smoothing unit (pictured in Fig. 6). These stood in a row on a substantial wooden bench. The original design was rated at 100 watts, this being the power input to the self-oscillator, but in May 1924, after Post Office approval had been obtained, the power rating was raised to 200 watts. The circuit is shown in Fig. 7. A three-wire aerial on 3ft 6in. diameter ash spreaders, about 180ft long and anchored to a high point, such as a chimney, preferably 100ft or more above ground, was recommended. For the earth system a 20–30ft diameter ring of copper sheets, sunk edgewise 10ft into the ground and all connected to a common point at the centre, was the preferred arrangement. Where the nature of the ground made this impossible, a horizontal earth screen consisting of sixteen wires, 10ft above the ground, immediately under the aerial was recommended as an alternative. In the studio was a Marconi-Sykes microphone, reposing on a layer of sorbo rubber inside the traditional meat-safe. Where there was a ventilating fan in the studio, extreme caution was urged, for the fine leads from the moving coil were liable to fracture if the microphone got into the air-stream from the fan. Some of the earlier relay stations started off with Western Electric double-button carbon microphones, but they were soon replaced by Marconi-Sykes microphones. Adjoining the studio, with a window overlooking it, was the control room (Fig. 8). This was fitted out with a Marconi G.A.1 microphone amplifier, a Marconi correcting, or D amplifier for S.B. programmes incoming by line from London, a slide-back (see page 20) to indicate when the transmitter was on the threshold of overmodulation, and input and output plug boards for pro-

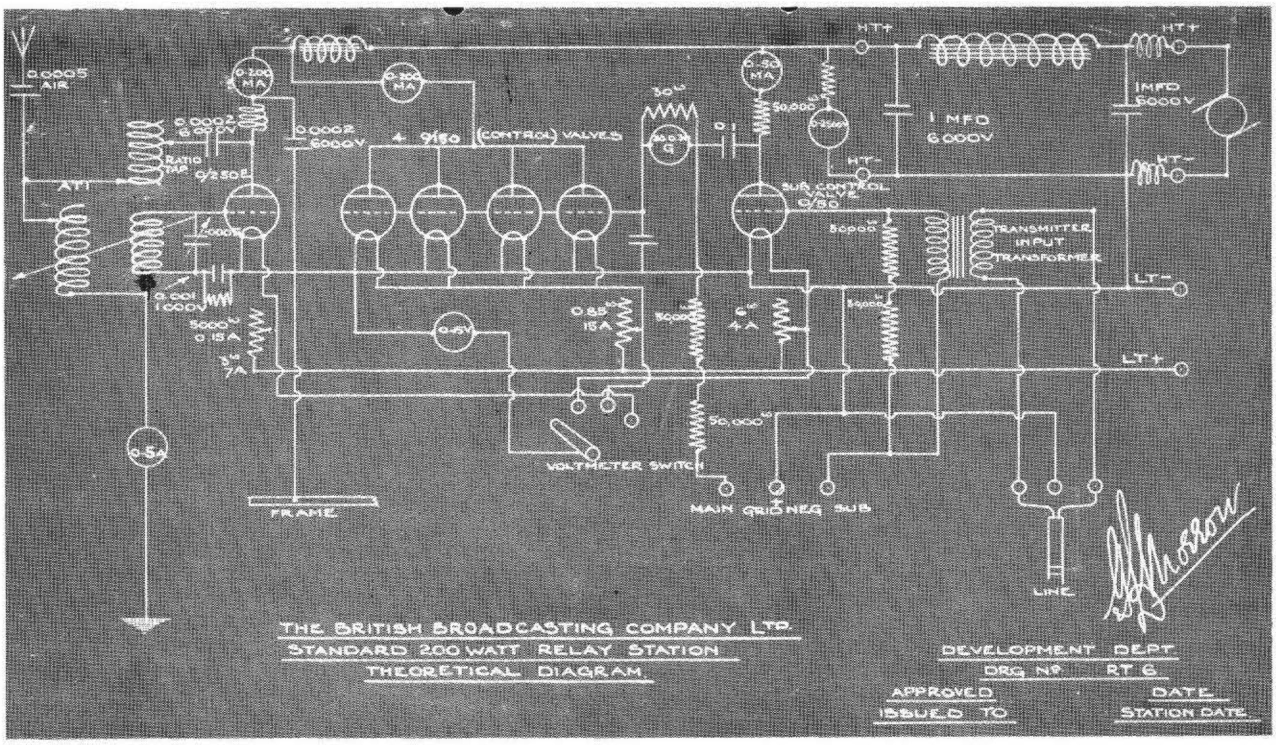


Fig. 7 Circuit of standard relay-station transmitter.

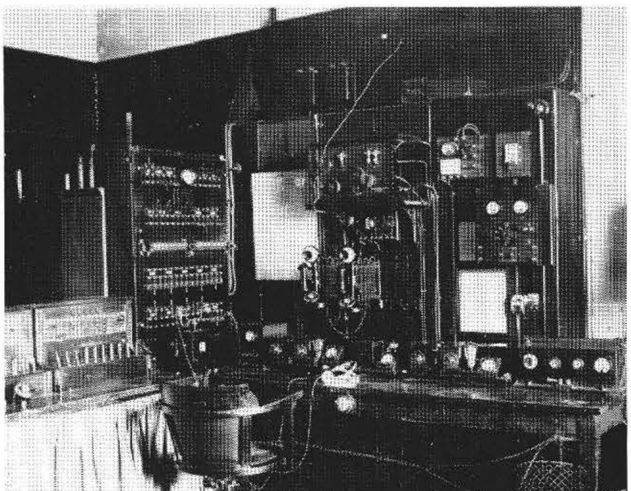


Fig. 8 A typical relay-station control room (87 George Street, Edinburgh). On the table can be seen two correction amplifiers, with a slideback between them, and (right) a Type 3 line amplifier.

gramme routing and telephone switching. Later on a BBC type 3 amplifier, for feeding the line to the transmitter, was added. The only difference from the main station control rooms, apart from the amount of equipment, was that the latter were fitted with Marconi G.K.1 control amplifiers as well.

Edinburgh, which opened on 1 May 1924, was the first relay station to have one of Walker's standard 200-watt transmitters, and thereafter they were installed at Liverpool, Leeds, Bradford, Hull, Nottingham, Dundee, Stoke-on-Trent, and Swansea. The two earlier relay stations, Sheffield and Plymouth, started off with 100-watt transmitters, but were brought into line during May 1924.

The thickly populated areas of Leeds and Bradford, just under nine miles apart, were something of a special case. As one of the standard 200-watt relay transmitters would not have been man enough to cover both areas – crystal set reception out to ten miles was reckoned to be about the limit – the BBC's first reaction was to go for a 500-watt transmitter. A site was found at Rawdon, roughly equi-distant from Leeds and Bradford, in the old boys' wing of the Rawdon's Friends Boarding School. In the event, however, the problem of interference from a transmitter of this power proved insuperable, and the Rawdon plan had to be abandoned. Instead, Leeds and Bradford each had their own 200-watt relay station, and a common studio in Basinghall Street, Leeds.

The relay stations were not without their troubles in the early days. Edinburgh, for example, when it started up in May 1924, gave a most disappointing performance and there were numerous complaints from listeners. The BBC took this seriously. 'Everything is not entirely satisfactory at Edinburgh', reported *Amateur Wireless*. 'It has been very difficult to get a really good earth connection, and the aerial is not all that might be desired. Mr Kirke* has gone to Edinburgh and will remain there until everything has been put right. If all else fails, he may even go to the length of looking for a new site.' It turned out that the aerial was fixed to a chimney lined with metal, a state of affairs of which the BBC were quite unaware when it was erected. The aerial had to be altered, and after that listeners reported greatly improved reception.

A. G. D. West noted this effect in a contribution to the 1925 *Year Book of Wireless Telegraphy and Telephony*. 'A curious effect is noticed,' he wrote, 'when chimneys have metal linings,

* See page 29, section 2

as the majority of them do. In this case very considerable absorption may take place, also the production of curious harmonics in the transmission due to the chimney itself resonating at certain definite frequencies.' He went on to stress the importance of the earthing arrangements. 'In the case of the eleven relay stations that have been erected those with the shortest earth-leads have given the most satisfactory results, independent of the height and constitution of the aerial; the method used being to bury very large copper earth plates under the transmitter, the lead being brought up through a drain pipe direct to the transmitter earth terminal. It is thus possible in dry weather to keep the earth moist by pouring water down the pipe and this maintenance of an efficient earth has the satisfactory result of keeping the radiation of the set practically constant under all conditions.'

Troubles of a quite different kind were encountered at Liverpool and Leeds. At Liverpool the BBC unwittingly picked on a transmitter site at Milner's Safe Works in Smithdown Lane which was only 600 yards away from the Army's Territorial HQ. Two months after the station opened the Post Office wrote to say that the BBC's transmissions were seriously interfering with the training of the Wireless Section of the 55th Divisional Signals, and that in the circumstances the Postmaster General could not approve the site. The Army Council, who had complained to the Post Office, evidently did not attach much importance to broadcasting, for they blandly insisted that as soon as the soldiers returned from camp the station must close down between 7.30 a.m. and 9.30 p.m. on Mondays, Wednesdays, and Thursdays. The BBC protested vigorously, pointing out that there would be considerable public indignation if the station had to move, which would not, in their opinion, tend to increase the popularity of the Territorial force in Liverpool. But the Army Council were not to be swayed by these protests. They declared themselves satisfied, after careful consideration of the BBC's representations, that military requirements were such as to leave no alternative to the removal of the station from its present site. As an act of grace, however, they were prepared to waive the restrictions on transmission hours until 6 November. The BBC had no choice but to give way. At the beginning of November the Smithdown Lane transmitter closed down, and a new station at the Corporation refuse destructor in St Domingo Road took over the service.

Exactly the same thing happened at Leeds. The transmitter at S. H. Sharpe's works in Claypit Lane was very close to the Gibraltar barracks, and the Army complained of interference to their Territorial Signal Headquarters there. As at Liverpool the Army Council stipulated that the BBC must move to another site at least three-quarters of a mile away or close down whenever the Territorials' station was working. Once again the BBC bowed to the inevitable. In November a replacement transmitter at the Corporation destructor plant in Stanley Road took over, and the Claypit Lane station closed down.

Relay stations were not the Army Council's only target. In the summer of 1925 they proposed closing down 5XX, the long-wave station at Daventry, on the grounds that it would interfere with Army communications during manœuvres. But this time they met their match. The proposal caused a good deal of sarcastic comment among listeners and in the Press. 'What the wireless men want to know,' a correspondent in the *Evening News* declared, 'is why don't the War Office have Salisbury Plain mown as well, and put a roof over it in case it rains?' No more was heard of the proposal after that.

In seeking sites for the relay stations the same considerations applied as for the main stations. Factory sites predominated, their tall chimneys being an obvious attraction. No less than seven of the transmitters were on factory premises, and another two were at refuse destructor plants. In company with the main stations all the relay stations, except for Sheffield, had the studio and transmitter on different sites. Sheffield, however, came into line with the others in April 1925 when a new studio in Castle Street was opened.

On the completion of the relay station scheme in December 1924 it was reckoned that something approaching another seven million people had been brought within reception range. This meant that the BBC's medium-wave coverage was now twenty-nine million, corresponding to 65 per cent of the population.

4 Savoy Hill

In 1923 the Company moved into Savoy Hill, that most memorable and evocative of BBC addresses. The second and third floors in the west wing of the Institution of Electrical Engineers building on the Victoria Embankment were taken over. Occupation started in March and by the end of April it was complete.

There was one studio to begin with, on the third floor (Fig. 9). It was opened on 1 May. By the standards of the time it

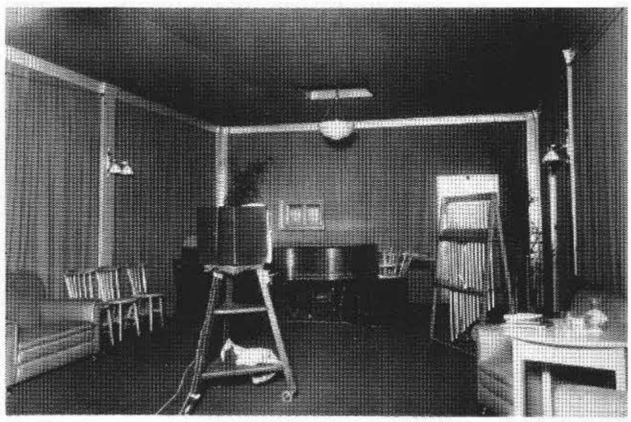


Fig. 9 The original studio at 2LO Savoy Hill, May 1923. The walls were hung with golden netting, which was relieved by blue panels. *Wireless World*

was big, $37 \times 18 \times 11$ ft high, a considerable advance on the cramped studio at Marconi House. As was customary then it was very heavily damped. 'Five tons of canvas and wood served effectively to silence all echo in the studio', reported the *Wireless World*. The walls and ceiling were covered with six layers of hessian cloth stretched on wooden frameworks with an inch or so air-space between them, and on the floor there was a deep-pile carpet. This treatment was successful in that it brought the reverberation time down to something under a quarter of a second. On the other hand, the extreme deadness imposed a severe strain on the artists. There was something unnatural about it which had an acutely depressing effect on their spirits. As A. C. Shaw, the first Engineer-in-

Charge at Savoy Hill, put it, 'It was very heavily draped, which damped not only the studio but the ardour of the artists as well.'

The heavy damping may have hampered the artists, but it helped the engineers. With its freedom from standing-wave effects the studio proved an ideal testing ground for microphones. The Marconi-Sykes magnetophone, for example, went through all its experimental stages in the old studio at Savoy Hill.

A second studio followed in January 1924. Situated on the first floor, with dimensions 44 × 26 × 18 ft high it seemed really enormous at the time. By then the BBC had modified its thinking on acoustics, and no attempt was made to smother the echo completely. Absorption was applied with a much lighter hand, only one layer of hessian cloth being used, with draped curtains for decorative effect. An effect of sunshine was created by giving the windows a silver-leaf background and concealing electric lights behind the green and gold hangings. After a while the hessian was removed and curtains were hung on rails so that they could be drawn aside to expose the bare walls. These alterations increased the reverberation time from 0·7 s to a figure variable between 0·9 and 1·3 s.

In August 1924, to keep pace with expansion, the north-west corner of the site overlooking the Savoy Chapel was leased. This corner was one of the last relics of the Zeppelin air-raids over London during the war. After being struck by a bomb a section had remained exposed as if it had been left deliberately for exhibition, with grates and chairs and other pieces of furniture just as they were after the bomb fell. By the end of 1925 three studios had been created in this part of the building. The first to be ready was Studio 5 – it went into service on 7 November – a small studio for the news and talks. The acoustic treatment consisted of a 1 in. layer of hair felt with curtains draped over it. 'The broadcaster who comes to deliver a talk will be able to do so under ideal conditions, in a small cosy sanctum, specially built and specially reserved for talks, with a comfortable chair drawn into a gently sloping desk on which his manuscript lies – lit by an adjustable standard lamp,' promised the *Radio Times*. 'The microphone will be at the top of the desk at the desired distance from the speaker, and the room is to be draped and carpeted so as to give the best possible echo effect.'

Studio 4 was the next to be completed. Of medium size – 44 × 21 × 11 ft high – it was devoted mainly to variety programmes and was the first studio to incorporate drapings on the walls and ceiling which could be pulled aside to alter the acoustic.

The last of the three studios in the north-west corner to come into service was Studio 2. Designed for drama productions, this was a more elaborate affair, with an effects room and an echo room leading off the studio through communicating doors. The sounds reaching the echo room from the studio were picked up on a microphone and then mixed in with the direct sound from the studio. The combination of a loudspeaker and microphone for artificial echo was not used until the summer of 1926 when an echo room remote from the studio was introduced at Savoy Hill.

Until the advent of these additional studios the original ones had been loosely referred to as the 'old' and the 'new' studio. To distinguish them it now became necessary to give them a number. The old studio became No. 3, for the not very profound reason that it was on the third floor, and the new studio, which was on the first floor, became Studio 1.

The silence cabinet, which became such a familiar feature of the Savoy Hill studios, was introduced at this time. It was a rectangular wooden kiosk, about 6 × 4 ft, with windows in the upper half, set down in one corner of the studio. In it sat the announcer or the producer. He was provided with headphones for listening to the studio output and a microphone for announcements. This arrangement was first tried out in Studio 4. The studio microphone or the one in the silence cabinet was selected by a change-over switch. Lamps on the outside of the cabinet indicated which microphone was alive.

The arrangements in Studio 2 were slightly different. There the silence cabinet was in the effects room with a window overlooking the studio. Instead of a change-over switch there was a fader for each microphone – in the studio, effects room, echo room, and silence cabinet.

Silence cabinets were not altogether successful. It was difficult to make them really soundproof and impossible to get the desired acoustic in such a confined space. By 1927 they were beginning to give way to listening rooms constructed outside the studio with a window overlooking it.

By August 1926 a sixth studio had been completed on the first floor of the north block. This was Studio 6, for talks and piano recitals. Acoustically it broke new ground by dispensing with the heavy drapes on the walls that had been the rule so far. Instead, most of the walls and part of the ceiling were covered in hair-felt overlaid with wallpaper, so that it looked

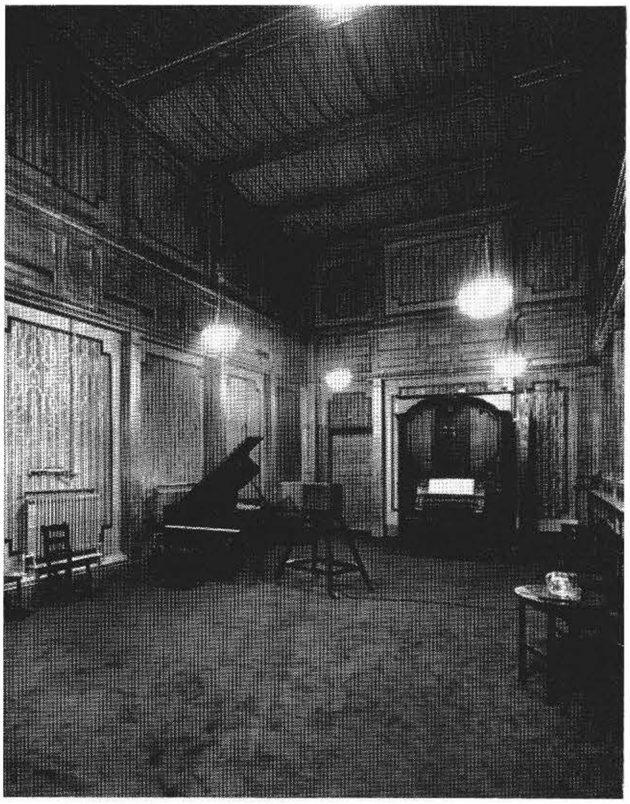


Fig. 10 Studio 7 Savoy Hill, opened in January 1927. With its rich gold-and-brown colour scheme it was familiarly known as 'The Corner House'.

like an ordinary room. 'The results,' wrote A. G. D. West, 'have turned out extraordinarily well up to expectations, and have so far justified the use of the new method.'

The design of the next studio to be completed, No. 7, was profoundly influenced by a series of outside broadcasts that started in 1925. On 28 July Daventry carried an hour's programme by 'Sandler and his Orchestra' relayed from the Palm Court of the Grand Hotel, Eastbourne. A second programme followed on 27 December, and there was a succession of them in 1926. These Albert Sandler broadcasts created a great impression. *Amateur Wireless* commented, 'During the last few months we have had two transmissions relayed directly from the Grand Hotel at Eastbourne, and each of them has been absolutely first rate. The chief reason for this seems to be that the orchestra and the soloists are performing in a room which has exactly the right amount of resonance for the microphone. There was about the music a "realness" and a richness of tone that one misses in transmissions from the studio. On the following evening when one tuned in 2LO the difference in the quality of the two transmissions was extraordinary. The first had been rich and mellow, the second sounded very much muffled and certainly had no depth. . . What I believe is needed is a studio whose acoustic properties are not unlike those of a small concert hall.'

Studio 7 (Fig. 10) was built with the express intention of emulating these qualities. It was big, 43 × 20ft, and lofty – 22ft 6in. high – taking up the full height of the first and second floors in the north block. The acoustic treatment was on the same lines as in Studio 6, consisting of half an inch of hair felt on the walls with wallpaper on top. A layer of Celotex and a thick carpet covered the floor, and there were heavy drapes on the ceiling, which could be drawn back at will to increase the reverberation time from about 0·8 to 1·6s.

A. G. D. West was well satisfied with the results. 'The overall reflection is fairly even for all frequencies,' he wrote in the *Wireless World*, 'the low tone introduced by the felt being compensated by the high tone reflection of the covering paper and of the wood panelling, pillars, and organ. The "room effect" is reduced in favour of a tendency to "hall effect". This is on account of greater volume, and the breaking of reflections by the pillars. The studio has, on account of its scheme of decoration and loftiness, a feeling of freedom which is much appreciated by artists.'

At first the amount of technical equipment at Savoy Hill was minimal. In the studio there was Round's magnetophone, still very much in the experimental stage with an improvised-looking housing. Next door to the studio with a window between them was a small room, variously referred to as the control room or instrument room. Here an engineer monitored the programme on headphones and signalled, by hand, to the announcer in the studio if he wanted the artist to move nearer or farther away from the microphone. There was no control room in the accepted sense of the word, only an amplifier room containing a single microphone amplifier of prodigious proportions, and a simultaneous broadcast (S.B.) room where the lines to the provincial station and the transmitter at Marconi House terminated.

This primitive phase did not last long. By April 1924 a control room had been created on the third floor (Fig. 11). It was fitted out with two control positions, a new and bigger S.B. board, a check receiver for the 2LO transmissions, and

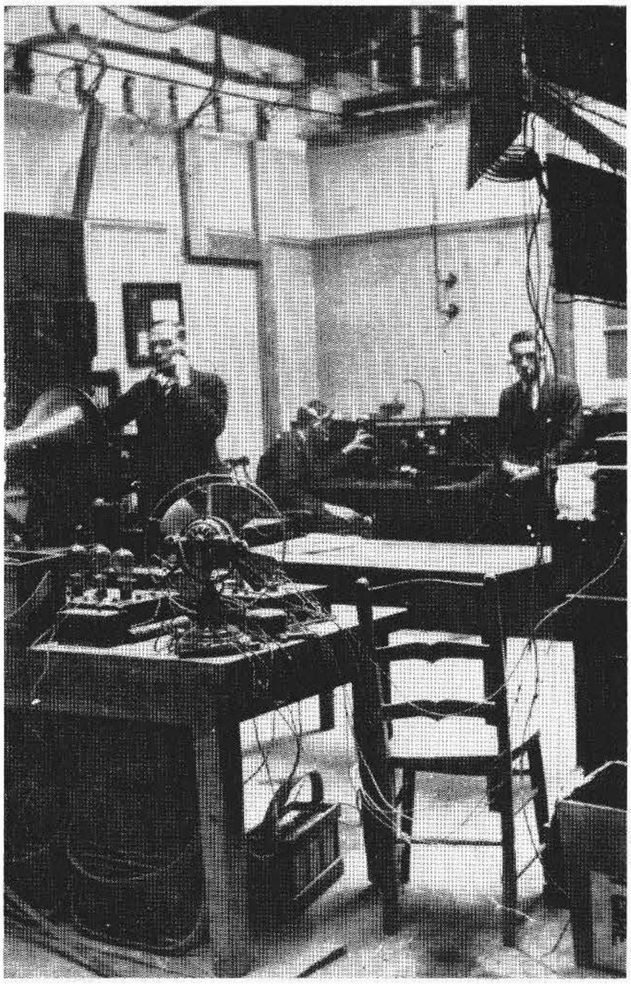


Fig. 11 The original control room at Savoy Hill, 1924.

the Greenwich time signal and Big Ben amplifiers. Each control position (Fig. 12) consisted of a long table carrying an input board for selecting the programme source, e.g. one or other of the two Savoy Hill studios, Big Ben, Grenwich time signal, or an O.B. point (there were seventy-five permanent O.B. lines at this stage), a Marconi G.K.1 control, or B amplifier, on which the engineer controlled the programme level, a slide-back (see page 20) for indicating when the level was reaching overload point, and an output board for programme destination routing. Eckersley was proud of his new control room – 'You will soon see, if you are shown round,' he wrote in *Radio Times*, 'a most beautiful room with brass rails and wonderful plug boards, with all the wiring in wood casing and the whole place reminiscent of a fire station.' At the same time the gargantuan microphone amplifier was superseded by Marconi G.A.1 amplifiers installed close to the studios.

In 1925 the control room was enlarged. By this time there were 200 permanent lines to O.B. points. Two more control positions were added in order to cope with the new studios – Nos. 2, 4, and 5 – which were commissioned at the end of the year. An entirely new and much more elaborate S.B. set-up, complete with control desk, was also installed. At the same time the opportunity was taken to install a centralised battery system.

During 1926 a line corrector desk for testing and equalising

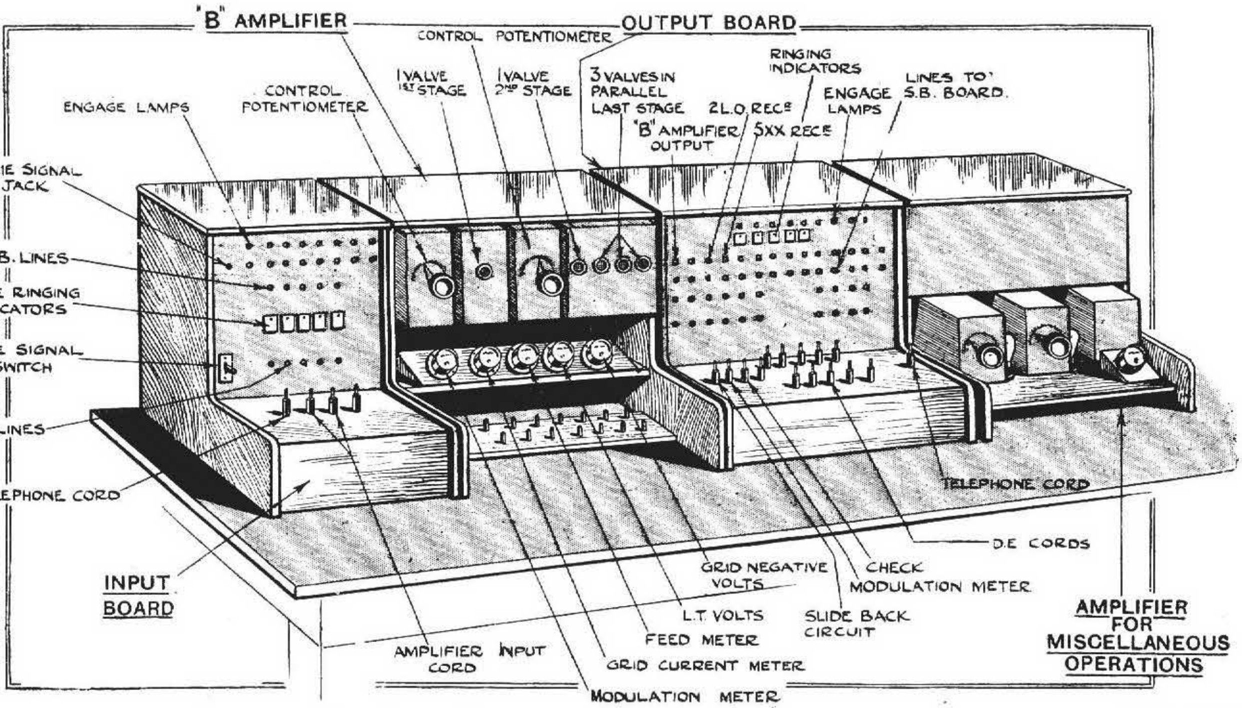


Fig. 12 Arrangement of control position, Savoy Hill. *Wireless World*

outside broadcast lines was installed. Shortly after this, early in 1927, changes in the studio A amplifier arrangements were introduced. By then the Marconi-Reisz microphone had replaced the Marconi-Sykes, and its greater sensitivity made it unnecessary any longer for the A amplifier to be located very close to the studio. So the Marconi G.A.1 amplifiers, which were scattered all round the building, were replaced by amplifiers of BBC design concentrated in a room on the first floor of the north block.

5 Simultaneous Broadcasting

It seems almost incredible now, but to begin with each BBC station was completely isolated from its fellows with no means whatever for sharing or exchanging programmes. The first steps towards breaking this isolation were taken in March 1923. Encouraged by the success of the relay from Covent Garden in January, the BBC got the Western Electric Company and the Post Office to carry out a test between London and Birmingham to see whether music could be transmitted over greater distances on the ordinary telephone trunk circuits. The first test took place on the night of 20/21 March, with a Western Electric 8A amplifier at Birmingham feeding a line to Marconi House in London. A string orchestra, vocal items, speech, and solos on a 'cello, piccolo, and piano were included in the repertoire. According to E. K. Sandeman, the results were very much beyond expectation, the only serious distortion being due to the loss of the higher harmonics of the violin and the top notes of the piano. Another test was staged on the night of 16/17 April, this time from Glasgow. Despite the far greater distance, the results were even more pleasing, the explanation of this apparent anomaly being that the Glasgow-London route was equipped with much heavier open-wire lines – 600 lb per mile compared with only 200 lb on the Birmingham route. Both these tests were radiated by 2LO after close-down – they drew favourable comment in the technical press – but they can hardly claim to be the first simultaneous broadcast, since only one transmitter radiated them.

The first full-scale simultaneous broadcast, with all six stations (London, Birmingham, Manchester, Newcastle, Cardiff, and Glasgow) joining in, took place during the afternoon of Sunday, 13 May, with Marconi House originating the programme. It had been calculated that a sending level of close on +40 dB was needed to overcome the attenuation of the lines to the provincial stations, and to achieve this massive input a Western Electric 40-watt public-address amplifier was used to feed the outgoing lines. This first full S.B. test was an unqualified success from the BBC's point of view, but the Post Office's reaction must have been rather different. The tremendous sending level caused serious derangement of trunk-line traffic, a great many circuits being put out of action by the extremely high volume of cross-talk that occurred. Clearly, a more restrained sending level was essential. On 17 May another test was staged, this time with the input reduced to zero level, the difference being made up by amplifiers at the provincial stations. The 40-watt amplifier was replaced by six Western Electric loudspeaker amplifiers – one for each outgoing line. This reduction and the insertion of repeating coils successfully eliminated the cross-talk.

After this simultaneous broadcasting was put on a permanent footing. The first S.B. board (Fig. 13), consisting of seven Western Electric loudspeaker amplifiers, each with its repeating coil and a potentiometer for impedance matching, was installed in a room on the third floor of Savoy Hill, and arrangements were made with the Post Office for a special circuit from London to each of the provincial stations to be handed over every evening. Regular simultaneous broadcasts started on 29 August when the new bulletins at 7 o'clock and 9.30 from the Savoy Hill studio were broadcast simultaneous-

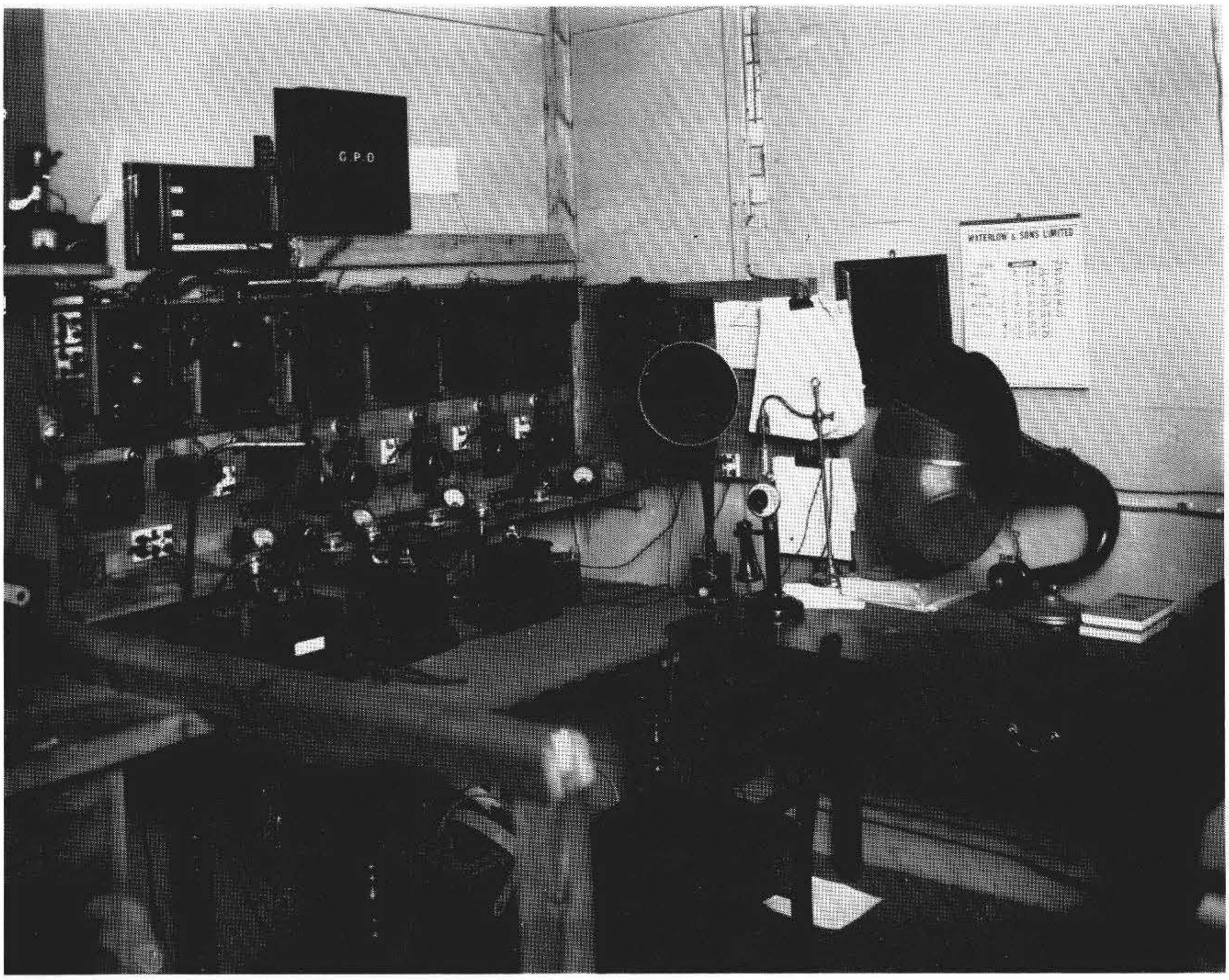


Fig. 13 The simultaneous-broadcasting room at Savoy Hill, January 1924. *Marconi*

ly by all stations for the first time. Simultaneous broadcasting of musical programmes followed in October. S.B. caught the public imagination on 12 September when Sir Ernest Rutherford's presidential address to the British Association meeting at Liverpool was broadcast by all stations. 'The experiment by which Sir Ernest Rutherford's address on the size of the atom was heard from end to end of the British Isles simultaneously is an achievement unsurpassed by any other country', declared the *Sphere*. *Radio Times* echoed these sentiments, 'A historic milestone in the history of wireless was reached the other night by the broadcasting of the Presidential Address of the world-famous scientist, Sir Ernest Rutherford, at the British Association meeting at Liverpool. It was the first occasion in this or any other country on which the voice of a public man had been transmitted simultaneously through six wireless stations hundreds of miles apart.'

By the beginning of 1924 with nine stations already on the air, and a whole string of relay stations due to come into service before the end of the year, the original S.B. installation was no longer man enough for the job. A new S.B. board was therefore designed and built when the control room at Savoy Hill was created in April 1924. It was on much the same lines as the original one, with Western Electric loudspeaker amplifiers, but more extensive and more versatile.

In 1925 the S.B. system was completely re-jigged. Instead of each provincial station being fed by line direct from London, a measure of grouping was introduced. Peter Eckersley described in his usual graphic manner what was going on. 'Britain is divided into three parts,' he wrote in the *Radio Times*, 'Scotland, North England, and South and West England. Glasgow is the centre of one star and from it radiate trunk lines to Aberdeen, Belfast, Edinburgh, and Dundee. Leeds will form the centre of a second star connecting Newcastle, Manchester, Hull, Leeds, Bradford, Sheffield, Liverpool, and Stoke. London becomes the focus of Bournemouth, Plymouth, Cardiff, Swansea, Daventry, Birmingham, and Nottingham. It may be, in time, that another sub-division will be made, and that Bristol-London will be a main trunk route.'

Glasgow assumed this additional role early in 1925. Leeds, the repeater station for the northern group, was originally due to come into operation on 1 November, but there were setbacks, and it was not ready until early on in 1926. For the repeater station to feed Cardiff, Swansea, and Plymouth the choice ultimately fell on Gloucester in preference to Bristol, because this tied in better with the Post Office line routings. Situated in County Chambers in the Market Place, the Gloucester station opened on 1 December 1926.

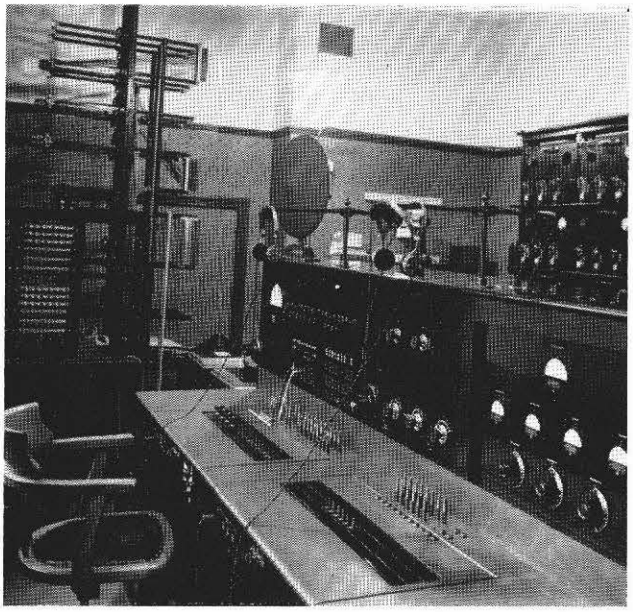


Fig. 14 Gloucester repeater station. *Wireless World*
Left, a bank of Sullivan equalisers; centre, combined control and correction desk; right, rack-mounted line amplifiers. On the desk an STC Kone loudspeaker, one of the best types available before the introduction of moving-coil units.

The line amplifiers at Leeds and Gloucester for feeding the dependent stations were of the same design as the ones at Savoy Hill. Leeds, like Savoy Hill, had a control desk for switching, routing, and monitoring, and a corrector desk for transmission measurements and equalisation. At Gloucester these functions were combined in a single desk (Fig. 14). Remote switching was a feature of the system, and by means of this the dependent stations could, as it were, help themselves to a programme feed from the repeater station by the simple action of plugging up the incoming line.

The role of the repeater stations was admirably summed up by the *Wireless World*. 'The chief function will be to improve the quality of all items received from London to the same excellence as when they left London. Distortion and other faults will be corrected, and weak signals will be given new life before they are passed on, so that listeners should get improved reception from many local stations, as well as a general speeding up in the S.B. part of the programme. The alterations will not only provide better reception but lead to considerable economies in the hire of what are, after all, unnecessary P.O. land lines.'

In London a completely new S.B. rig was installed during the enlargement of the Savoy Hill control room in 1925. Thirty two-stage line amplifiers with a gain of 18dB were ranged along one wall of the control room in glass-fronted cabinets. Immediately in front of the amplifier cabinets was the S.B. desk from which the system was operated. This installation came into service in November 1925. It was extremely versatile, and as many of the operations were carried out automatically, one engineer could easily control it. 'The action is semi-automatic,' reported the *Radio Times*, 'and, thanks to relays, all the processes can be easily supervised by one person. The design and construction are unique and in no part of the world has so up-to-date and far-reaching a scheme been evolved.' In 1926 a line corrector desk for transmission measurements and equalisation was added.

6 Studio Microphones and Amplifiers

In the early days of broadcasting probably the weakest link in the chain was the microphone. 2LO, like Writtle before it, started off with solid-back carbon microphones, as used in the telephones of the time. Manchester, likewise, used these carbon microphones to begin with, and so did Newcastle and Cardiff. Within a year, however, they had all been swept away, to be replaced by something better. This was not surprising, for the telephone-type carbon microphone was a most indifferent instrument. Its frequency characteristic (Fig. 15)

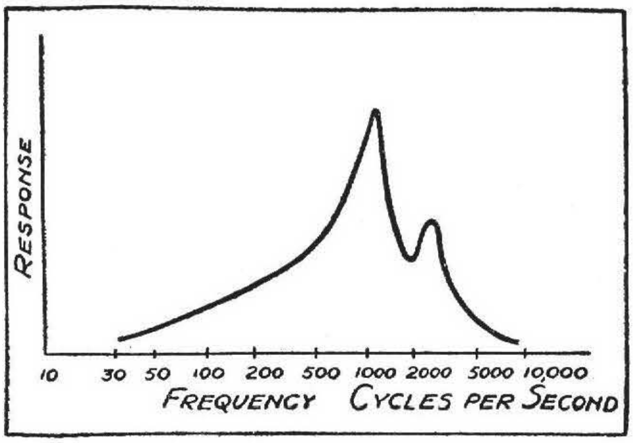


Fig. 15 Frequency response of telephone-type carbon microphone. (Plotted with linear vertical scale.)

was anything but level, with a pronounced peak at about 1kHz. It also generated a lot of background noise, in the shape of a most objectionable hiss. To override this, these microphones had to be used very close up, like a lip microphone, which must have been extraordinarily inconvenient for the artists. Another serious defect was the propensity of the carbon granules to coagulate, or pack as it was called, which resulted in a disastrous reduction in output. Arthur Burrows writing about the early days at 2LO, aptly commented, 'Ours was a carbon-granule microphone somewhat similar to that employed in an ordinary telephone mouthpiece. It resented being shouted at, and (as a bottle of medicine is) was at its best after a good shaking. Later we had six of them, five suspended like malefactors in mid-air, the sixth buried in the piano.'

Among the earliest stations Birmingham was the odd man out, so far as microphones were concerned. Set up by the Western Electric Company, it had the advantage of being able to use their 373 double-button carbon microphone, which had been developed in the Bell laboratories by a team of engineers headed by Maxfield. This had a push-pull arrangement to counteract the non-linear characteristics inherent in carbon microphones, and a thin, tightly-stretched steel diaphragm, with air damping to minimise resonances. The frequency response was substantially level from 90Hz up to 3kHz, but by 4kHz it was tailing off, after which there was a sharp rise at the resonant frequency of the diaphragm between 6 and 8kHz. Writing in *Popular Wireless* at the end of 1923 Eckersley paid a handsome tribute to the Western Electric carbon microphone. 'At the beginning of broadcasting we had only one type of microphone in this country that would adequately even look at the job. It was American, and all will remember the sensation caused in broadcast circles by the quality emanating from Birmingham. At Writtle we were using the ordinary carbons, and while, of course, our programmes (half an hour's gramophone a week) were wonderful, we had to admit our quality could not compare with Birmingham.' The Western Electric 373 microphone is seen in the photograph of the Birmingham studio in Fig. 1.

Cardiff and Manchester went over to Western Electric carbon microphones in August 1923, with Newcastle following suit soon after, and they were also used in the original studios at Glasgow and Sheffield. Their tenure was pretty short, however, for by the end of 1924 they had been ousted by the Marconi-Sykes microphone.

In 1922 Captain Round of the Marconi Company, perhaps spurred on by the success of the Western Electric Company, began to turn his attention to the development of better microphones. Early in 1923 he produced his electro-dynamic microphone, sometimes referred to as the Round microphone (Fig. 16). This worked on the same principle as a telephone

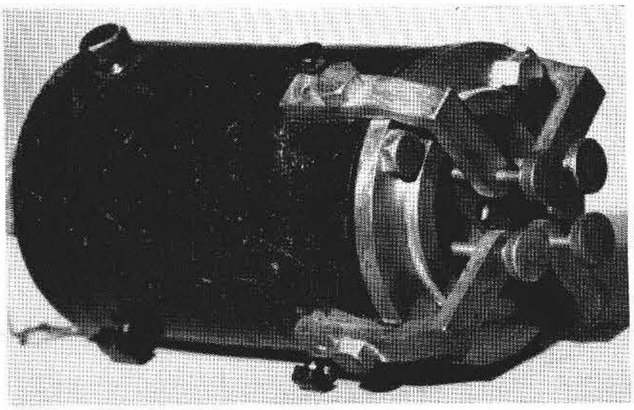


Fig. 16 Round electrodynamic microphone. The knurled screws are for adjusting the resonant frequency of the diaphragm. At Marconi House in 1923 four of these microphones, each tuned to a different resonance, were used together in one housing.

earpiece. It was much quieter than the solid-back carbon microphone, but as the diaphragm had a pronounced resonance, the frequency characteristic was not much better. Round attempted to get over this by using several of these microphones in parallel, with their diaphragms tuned to resonate at different frequencies. Four of these massive instruments – they weighed twenty pounds apiece – were mounted in a wooden box, with four large ports at the front, on a tripod. 'Like a howitzer battery,' Eckersley wrote in *Popular Wireless*, 'four great round iron contraptions, all over screws, precariously balanced on the top of the ungainly pile. Packing washers beneath these same screws varied from bits of yesterday's newspaper rolled in a wad to chunks of fibre collected from the scrap-box, and finally, quintessence of neatness, two sixpences shone in undiminished glory on the "S blaster", as the high note magnetophone was affectionately called.'

Round's electro-dynamic microphone was introduced in the Marconi House studio early in 1923. But it was not really a success and did not survive the move to Savoy Hill. The new 2LO studio there was equipped with a Marconi-Sykes magnetophone. 'A newly-devised microphone of extreme sensitiveness has been installed', reported the *Morning Post* on 2 May: 'the new microphones are stated to be extraordinarily sensitive', echoed the *Wireless World*. This new microphone of Round's was still very much in the experimental stage. Photographs of the new studio (see Fig. 9) show a large, rather ungainly looking box perched on a sturdy tripod on wheels, with a knife-switch on one of the legs for the magnetising supply. Within a few months, however, the design had been finalised, and the Marconi-Sykes magnetophone, complete with its meat-safe housing (see Fig. 10), which became almost a symbol of broadcasting in the early twenties, was in full production (Fig. 17). It was on show at the

Fig. 17 Marconi-Sykes moving-coil microphone of 1923, known as the magnetophone *Marconi*

All-British Wireless Exhibition at the White City in November, a feature of which was a replica of the Savoy Hill studio. From then on the magnetophone quickly became the standard

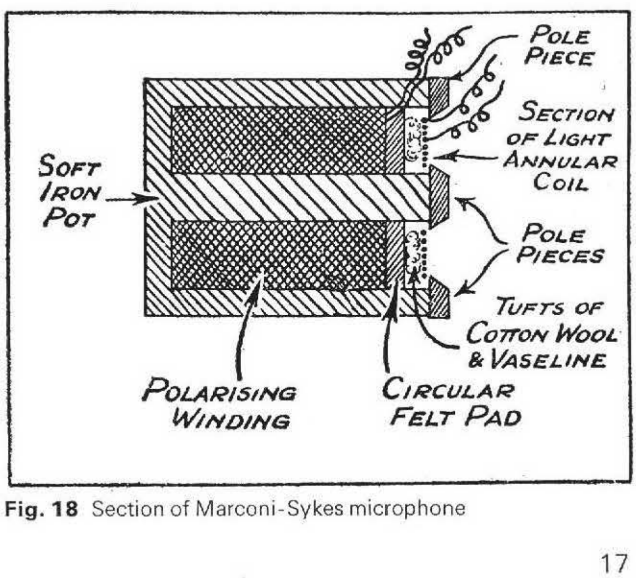


Fig. 18 Section of Marconi-Sykes microphone

studio microphone. The first provincial station to have one was Aberdeen, with Bournemouth a close second. By 1924, with one or two minor exceptions, it was in universal use.

The original idea for a microphone consisting of an electro-magnet and a pancake coil which also acted as the diaphragm (Fig. 18) came from the electrical engineer, Adrian Sykes, who patented it in 1920. Round developed this idea to the point where it was a practical proposition. For its time the magnetophone was a great step forward. It had a very linear response, and was almost free of background noise. Sensitivity was just about adequate, and its frequency response though nothing to write home about (Fig. 19), since there was at least one pronounced resonance and several lesser ones, was a good deal better than that of other microphones at the time.

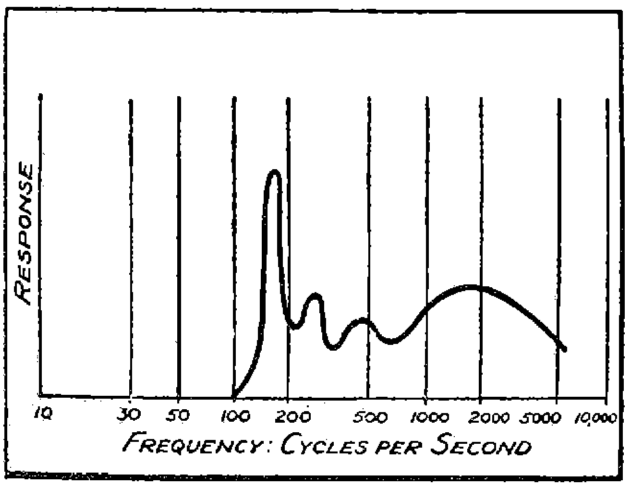


Fig. 19 Frequency response of Marconi-Sykes microphone. (Plotted with linear vertical scale.)

In 1925 Eugen Reisz, a Hungarian living in Berlin, perfected his carbon microphone. He used a block of marble with channels cut in it and filled with carbon dust, in which the electrodes were embedded. The carbon dust was kept in place by a thin skin of stretched rubber, which acted as the diaphragm. In the Marconi version, which the BBC used, a thin mica diaphragm was substituted for the stretched rubber, and this in turn was superseded later on by an impregnated paper diaphragm. The carbon dust was extremely fine, consisting of a mixture of particles varying in diameter from 0·07 mm to 0·0015 mm.

Eckersley was enthusiastic about the Reisz microphone. 'It is not unlikely we are on the eve of being able to use an arrangement responsive to all frequencies equally that requires but a two-valve amplifier', he wrote in December 1925. Although it did not quite live up to these high hopes, Reisz's microphone had many good points. It was compact and robust. Its output was far greater than the magnetophone's and, although it was not as quiet there was much less hiss than with other types of carbon microphone. The frequency characteristic (Fig. 20) was fairly good, with no prominent resonances. On the other hand, its response was not linear at high input levels, and so there was a risk of blasting if it was overloaded.

The Marconi-Reisz microphones made their bow at Savoy Hill towards the end of 1925. To begin with they were hung in the meat-safe, usually in pairs. Early in 1926 a double-decker version of the meat-safe, which enabled the microphones to be placed at a better height, began to appear, but this was short-lived and before long they were being suspended from the studio ceiling or from stands. By 1927 the Marconi-Reisz had swept the board, and it continued to be widely used until well on in the thirties.

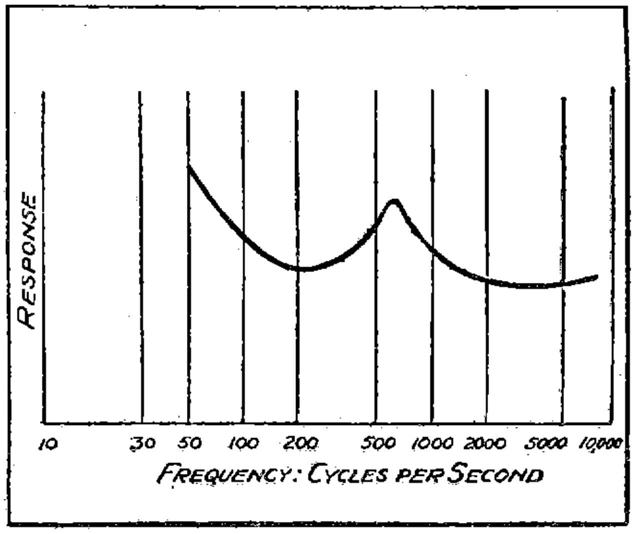


Fig. 20 Frequency response of Marconi-Reisz carbon microphone (1925). (Plotted with linear vertical scale.)

One other early microphone that deserves a mention is the Western Electric condenser, which was used in the Birmingham studios, but nowhere else. A product of the Bell laboratories and based on Wente's design of 1917, this had a tightly stretched steel diaphragm separated by about two mils from a corrugated back-plate. It had a rising frequency characteristic up to 1 kHz and a marked resonance, due to the diaphragm, at about 3 kHz. With the condenser microphone went a two-stage amplifier, housed with its batteries in a mahogany cabinet, which looked rather like a safe. The microphone and the amplifier were both very susceptible to the least trace of dampness and so were apt to be temperamental. Introduced in 1923 the Western Electric condenser microphone was still in use at Birmingham as late as 1926.

The primitive solid-back carbon microphones of 1922 and 1923 were connected straight through to the transmitter. Any idea of using a more distant balance and making up for the resulting loss of input by an amplifier was quite out of the question, because of the heavy background noise that they generated. By contrast, a more distant balance, with compensating amplification, was perfectly practicable with the double-button carbon microphone which the Western Electric Company used at 5IT Birmingham. Thus it came about that the BBC's first microphone amplifier, the Western Electric 8A, was to be found at Birmingham (Fig. 21). It was a thoroughly professional-looking piece of equipment, rack-mounted, with three choke-capacity coupled stages and input and output transformers. The 8A was always used with the Western Electric carbon microphone, and so by the end of 1923 it had achieved fairly wide currency in control rooms. Priced at £160, it was by no means a cheap amplifier.

When Round produced his electro-dynamic microphone and the magnetophone in 1923, they had to have an amplifier

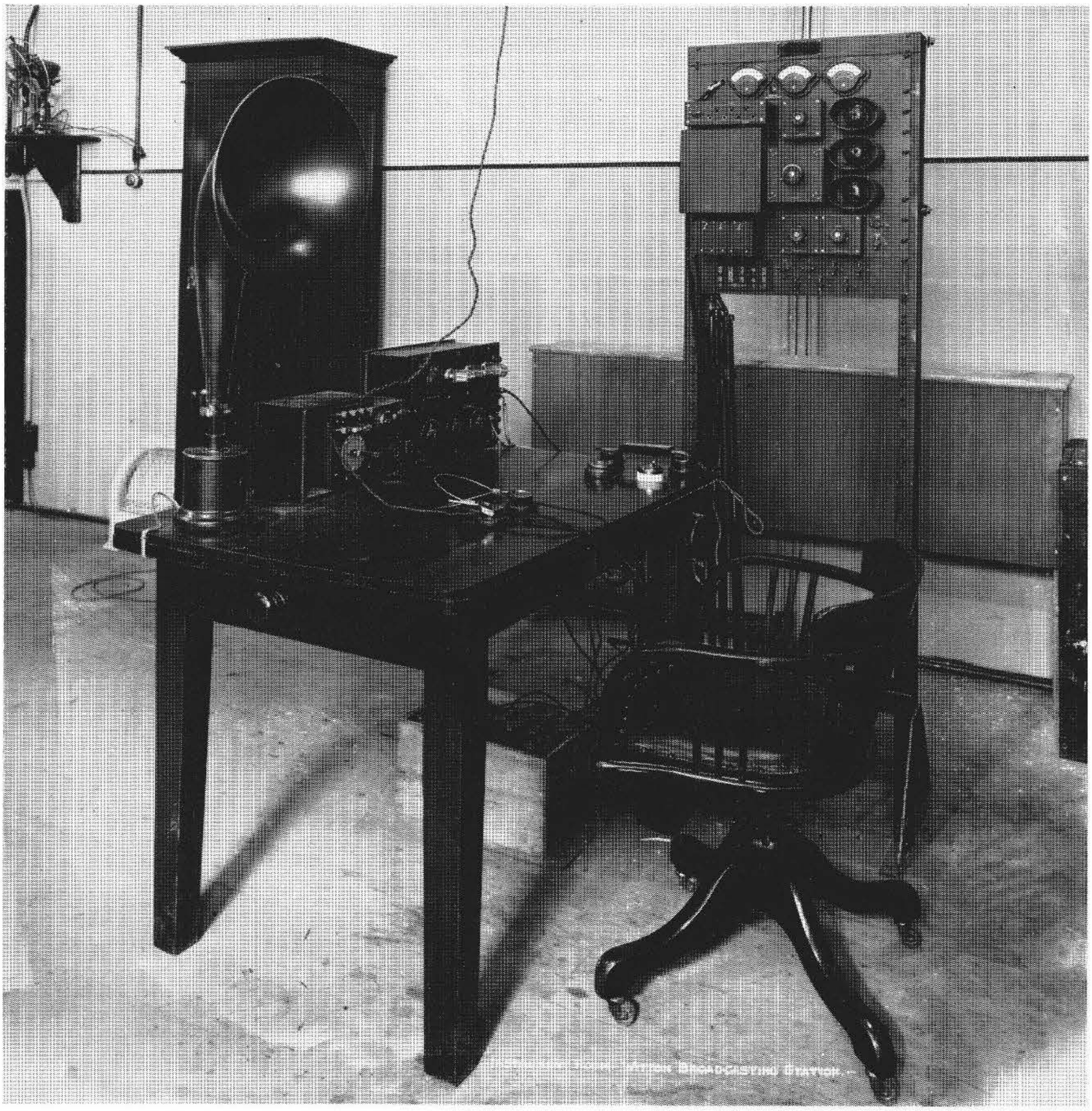


Fig. 21 The original control room at 5IT Birmingham with a rack-mounted Western electric 8A amplifier (right). On the table is a crystal detector with a three-valve audio amplifier for monitoring. *G.E.C.*

to go with them. No contemporary account of this amplifier has survived, but, happily, we have descriptions of it written by Sir Harold Bishop and A. C. Shaw, the Engineer-in-Charge of Savoy Hill, some years later. Apart from the extraordinary precautions that were taken to avoid microphony, the most striking thing about it must have been its gigantic size, somewhere between 6 and 8ft long, 4ft wide, and 2ft high. By the time the control room was created at Savoy Hill in April 1924 Round had developed his G.A.1 microphone amplifier, and for the next few years this was the standard BBC A amplifier. It had five resistance-capacity coupled stages with D.E.V.C. and D.E.Q. valves, though originally a Wecovalve was used in the first stage. Valves at that time were extremely sensitive to vibration, and to isolate them from any shock Round devised a mechanical filter consisting of a heavy staging suspended by elastic from a base on a sorbo mounting. Top-tip and top-cut circuits were incorporated in the couplings to the second and third valves. 'These two adjustments,' said the Marconi leaflet, 'enable the operator to balance the sounds in the different items reproduced as best to suit the acoustic properties of the hall in which the microphone is used.' Costing about £90, the G.A.1 was a good deal less expensive than the Western Electric 8A. At the same time Round's G.K.1 control, or B amplifier, made its appearance. This likewise became standard equipment. It had three stages, with three valves in parallel in the output stage, all LS5s. There were two

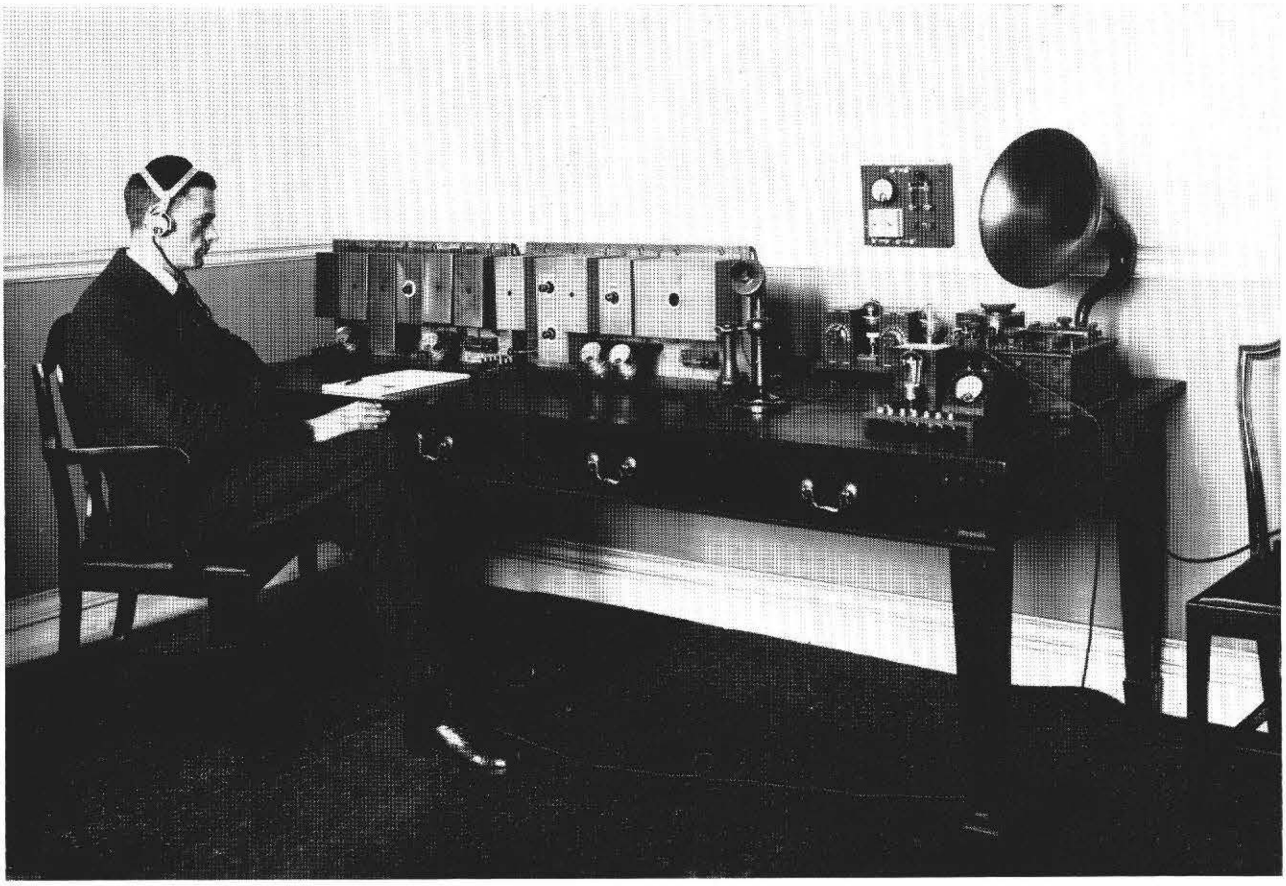


Fig. 22 Marconi control-room equipment, 1924. Left to right: G.A.I. microphone amplifier, G.K.I. control amplifier, correction amplifier, and (in front of the receiver) a slide-back. *Marconi*

controls, which enabled the gain to be set to within fine limits. It cost about £60.

Two other widely used amplifiers in the early days were the type 3 and the Marconi correcting, or D amplifier. Type 3, a product of the BBC's Development section, was a single-stage amplifier with two LS5s in parallel. It was widely used at the main and relay stations from 1927 onwards for feeding programme to line. The Marconi correcting amplifier, often referred to, rather confusingly, as a line amplifier, was for raising the level of programme incoming by line. It had two stages, with LS5 valves, and incorporated variable frequency correction to compensate for the characteristic of the line. It dates from 1924.

The other ubiquitous piece of control-room equipment was the slide-back, a valve rectifier which was set to pass current, and so indicate on a meter, when the programme level was reaching the point where the transmitter would be overloaded. Made by Marconi's, it was introduced in 1924. The G.A.1 and G.K.1 amplifiers, correcting amplifier, and slide-back are shown in Fig. 22. Except for the Western Electric 8A amplifier all this early equipment was for table-top mounting.

7 Outside Broadcasts

During the evening of Monday, 8 January 1923, 2LO broadcast part of the British Opera Company's performance of *The Magic Flute* from the Royal Opera House, Covent Garden. The Western Electric Company had installed one of their 373 double-button carbon microphones near the footlights, with an 8A amplifier below the stage, and the Post Office had put in a special underground cable to Marconi House for the occasion. This was the BBC's first outside broadcast, and it created quite a stir, even making a convert of Eckersley, who until then had been pretty sceptical about broadcasting. Years later he wrote 'Indifferent, and still in a spirit of mild and amused tolerance, I put on the 'phones and tuned to London at 8 o'clock or thereabouts. Directly I put on the 'phones my whole attitude to broadcasting changed, and I have never forgotten the thrill with which I suddenly sensed the feeling of a large auditorium and was translated from the prosaic interior of the Writtle hut into the front row of the stalls at Covent Garden. When the music itself came on I sat absolutely amazed for three-quarters of an hour, and from that day to this my belief that broadcasting has a great artistic future has never wavered.'

From then on outside broadcasts became a regular feature of the programmes. The most widely-used microphone to begin with was the Western Electric 373 double-button, but by 1924 the Marconi-Sykes magnetophone was taking an increasing share of O.B. assignments. Nevertheless, the double-button carbon microphone was still to be seen occasionally at O.B.s as late as 1927. For an amplifier the initial choice was the Western Electric 8A. A large and heavy piece of equipment, and designed for rack-mounting at that, it must have been extraordinarily unwieldy. The Western Electric two-valve loudspeaker amplifier was also popular for O.B.s initially. At Birmingham J. A. Cooper, the E.i.C., devised a suitcase assembly which incorporated this amplifier, suspended on springs, but by the time everything needful had been included it was a back-breaking weight. When the Marconi-Sykes microphone was taken to an O.B. it was always accompanied by a Marconi G.A.1 amplifier. Bulky and extremely heavy – with its stout teak carrying case it weighed over 100 lb – and very fragile, the G.A.1, no less than the 8A, must have been a sore trial to the pioneer O.B. engineers.

Radio, instead of the customary line link from an O.B. point, was used for the first time on Saturday, 23 November 1923. The Post Office were unable to offer a suitable circuit for an O.B. from the Old Vic, and so A. G. D. West decided to try a radio relay. A 30-watt transmitter was rigged up on the top floor of the Victoria tavern, next door to the theatre, and a 60-ft long receiving aerial on the roof of Savoy Hill. In this way the first act of *La Traviata* was relayed with complete success. *Amateur Wireless* was enthusiastic. 'The most outstanding feature recently has been the BBC's marvellous performance in transmitting opera from the Old Vic. It is little wonder that Captain Eckersley called November an historic night, for *La Traviata* came over to perfection'. A radio link was used again the following year, this time for an O.B. from the London Zoo, the transmitter being mounted on a trolley with a couple of bamboo poles to support the aerial.

During 1924 there were two particularly memorable O.B.s. On 23 April, with much pomp and ceremony, and in the presence of a great throng of people, King George V opened the British Empire Exhibition at Wembley. Nothing was left to chance. On the dais were duplicate Marconi-Sykes microphones, concealed in boxes covered over with gold cloth. The microphone amplifiers in the BBC kiosk, likewise, were duplicated, and there were no less than six lines to Savoy Hill, with a 200-watt transmitter in reserve. This was the first-ever broadcast by the monarch, and it made a tremendous impact. Estimates of the number of people who heard the king's speech ranged between five and ten million. *Wireless World* commended the BBC – 'The broadcasting of the opening ceremony of the Wembley Exhibition marked a pioneer British effort, and one which is likely to lead to still greater broadcasting enterprise in the future. The success of the transmission exceeded the most sanguine expectations even of those who were intimately associated with the carrying out of the work. The BBC must feel justly proud of the achievement.' The king's speech was recorded by HMV and repeated in the evening – the first time that this had ever been done.

The other memorable O.B. in 1924 could hardly have been more different. There were no crowds, no speeches, no pomp and ceremony. On 19 May a broadcast of dance music from Savoy Hill was faded out, and listeners heard instead the strains of Elgar's Concerto played by the 'cellist Beatrice Harrison in the garden of her Elizabethan cottage near Oxted. After a few bars the nightingales, evidently charmed by the music, began to join in. Listeners were enchanted. 'No one could have foreseen,' Reith wrote in the *Radio Times* a few weeks later, 'the extent to which the nightingale broadcast would catch the popular fancy. A little bird unconcernedly engaged in the pursuit of his personal affairs in a Surrey garden on an evening in May has swept the country (or such not inconsiderable portion of it as had the sense to listen to him) with a wave of something closely akin to emotionalism.' And the following year *Popular Wireless* commented, 'Opinions are divided as to who is the greatest artiste ever to broadcast in Britain, but a good many people would vote unhesitatingly for the one who is to give a repeat performance on May 30. This is the Surrey nightingale, whose song last year brought the BBC a chorus of praise from all over the world.' For the original broadcast A. G. D. West perched a Marconi-Sykes microphone on a stool on the edge of the woods bordering the garden, with a G.A.1 amplifier in the summer-house. The following year the microphones and amplifiers were duplicated, the idea being to try and capture a dialogue between a pair of nightingales (Fig. 23). *Wireless World* drew attention to the hazards of this kind of broadcast – 'The difficulties of broadcasting from an open spot are accentuated by many minor interferences. The buzzing of flies, for instance, and even midges cause a good deal of inconvenience, as they are attracted to the microphone by the heating up of the magnetising coil.'

1925 was notable for some unusual O.B.s. The trend had started at the end of 1924 with a broadcast by the Whitwood Colliery Band from 1500 ft below ground in the mine. Next came a broadcast from a train. It was the centenary of the railways and to mark the occasion the BBC staged a broadcast on 30 June from the Scotch express as it travelled northwards that evening from King's Cross. A transmitter, suspended in slings to insulate it from shock and vibration, was rigged up in a brake-van with a horizontal aerial just above the roof. Roger Eckersley was on the footplate with the microphone, talking to the driver and one of the railway company's engineers. The transmission was picked up on a receiver at Hatfield, using as an aerial one of the telegraph wires between Potters Bar and Hitchin, which had been specially isolated for the occasion. According to *Amateur Wireless* the broadcast was, on the whole, a success, with many of the characteristic footplate sounds coming through very well indeed.

In more placid vein were two O.B.s from Plymouth during the summer. A Marconi-Sykes microphone was set up at Bovisand Bay and the sound of waves breaking on the beach sent up the line to Savoy Hill as background for a play. On another occasion the song of the skylark, blackbird, and blue jay was picked up with a microphone at Fort Austin.

On 13 November these novelties culminated in a concert from the air. The Savoy Orpheans band, accompanied by several well-known artists, did a broadcast from a Vickers Vanguard circling over Croydon, the transmission being picked up at Keston. With twenty people on board, not to mention the piano, it was quite a scrum. Two microphones 'of a special carbon type' – most probably the Reisz which was just coming into use then – were rigged up in the cabin. The main problem was the noise from the 650 h.p. Rolls-Royce Condor engines, which was terrific. The microphones were swathed in thick layers of cotton-wool and used with a very close balance, and the transmitter modulation was stepped up to the limit. *Amateur Wireless*'s verdict on the broadcast was probably a fair one – 'It was a unique feat in the way of a transmission. But as a piece of broadcasting it was not very successful, since owing to the noises in the cabin of the aeroplane even when the engine was switched off it was difficult to hear spoken words, and the music had a background that was anything but silent.' This was much the most

Fig. 23 O.B. equipment for the 1925 nightingale broadcast installed in the summerhouse in Miss Beatrice Harrison's garden. By the G.A.I. microphone amplifiers is A. G. D. West, Head of Research. *Wireless World*

ambitious broadcast from the air, but not the first – the honour for this goes to the comedian John Henry, who broadcast from an aeroplane over London on 2 September 1924.

In 1926 the first amplifier specifically designed for O.B. work made its appearance. This was the type 1, a product of the BBC's Development section. Contemporary photographs show a teak box with a hinged lid, but no details of the circuit have so far come to light. The type 1s were soon supplemented by G.A.2 amplifiers, which Marconi's had brought out in 1926 to go with their Reisz microphones. The G.A.2 had three resistance-capacity coupled stages with D.E.5 valves, and input and output transformers. It was a truly portable amplifier, quite small and light, weighing only 18 lb compared with the 104 lb of the G.A.1. It is a measure of the popularity and success of the G.A.2 that it was still to be found on O.B.s as late as 1935. Three-channel microphone mixers made their appearance at about the same time as these amplifiers. The type 5, a bulky four-stage amplifier of BBC design, appeared in 1927, just in time for one to be used on the Boat Race O.B.

O.B.s in the early days were not without their setbacks and disasters. The Derby is a case in point. In 1925, for the third time of asking, permission to broadcast the race was at last forthcoming. The BBC proudly announced 'for the first time non-racegoers will be able to hear the shouts of the bookmakers and the yells of the crowd, and the pound of the hoofs as the horses swerve round into the straight run that ends the world's most famous race'. But it was all in vain. A few minutes before the race the Post Office lines failed, and the O.B. was a total loss. Nothing daunted, the BBC tried again in 1926. This time there was no technical trouble, but it was a pouring wet day and as a result there were hardly any sounds for the microphone to pick up. Once again the broadcast was a wash-out.

In May 1925 *Popular Wireless*, no doubt with a touch of hyperbole, reported: 'The first breakdown which affected the whole of the British Isles was a colossal failure during an important O.B.' A relay of the American Ambassador's speech at the Pilgrims Dinner was scheduled from the Hotel Victoria in Northumberland Avenue for the evening of 4 May. When the amplifier at the O.B. point failed, the spare was promptly substituted. But as luck would have it, the spare immediately burnt out as well, and so the O.B. had to be abandoned. It was then up to the studio to fill the gap. But the studio was empty save for a solitary announcer, who had nothing to announce, and so there was a prolonged period of silence.

Then there was the outbreak of wire-slashing. In November 1925 *Popular Wireless* reported: 'The latest wire-cutting outrage to interrupt broadcasting is reported from Manchester, where a determined attempt was made to spoil the charity concert which the BBC had organised and was broadcasting from Holdsworth Hall on behalf of the Nicholls Boys' Hospital. Not only the main line, but also the spare line was cut, and in a place that was difficult of access, so that it was obviously a carefully prearranged attempt. Police investigations served to cast doubt on the popular local theory that a practical joke was intended. Only a few days before, wires involved in the broadcasting of the Crowland bells from Peterborough were similarly cut, but on that occasion the malefactors forgot the reserve wire.' The lines to Crowland were tampered with again in February 1926, but fortunately it was possible to use another route, and so the broadcast went ahead, though later than originally intended.

1927 was the year of emancipation for outside broadcasts. Until then the BBC had been expressly prohibited from broadcasting commentaries on events as they happened. On 1 January 1927 these shackles were removed, and a new chapter for O.B.s began. The honour of being the first event on which a running commentary was broadcast went to the England v. Wales rugger match at Twickenham on 15 January. *Radio Times* commented: 'It can be said without contradiction that the broadcast description of the England v. Wales match constituted one of the most important events since the inception of broadcasting in this country, marking as it did the beginning of a new era in wireless.' Thereafter running commentaries followed thick and fast – the Open Golf Championship, the Cup Final at Wembley, the Derby, the Grand National, Trooping the Colour, and Wimbledon being among the events covered. But the new-style O.B. that caught the public imagination above all others was the Boat Race. The launch *Magician* was hired from Hobbs and Sons at Henley and fitted out to transmit a commentary from a position just astern of the crews. As Marlow lock was closed for repairs at the time, she had to be brought round from Reading to Brentford on the Great Western Railway. The Post Office agreed to a 100-watt transmitter on 115 metres, and this was placed in the stern with an aerial 11 ft above the waterline between two masts fore and aft. Two Reisz microphones were fitted up in the bow with duplicate O.B. amplifiers. Two receiving points were established in Barnes for picking up the commentary from *Magician* and sending it on by line to Savoy Hill (Fig. 24). One was in the research room of the Radio Communication Company's works in the High Street, and the other at 105 Castelnau, which belonged to the radio frequency engineer, Kenyon Secretan.

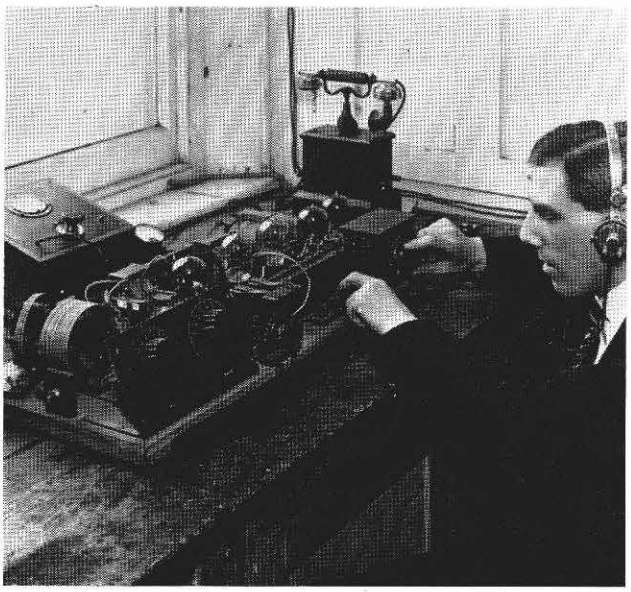


Fig. 24 Oxford and Cambridge boat race, 1927. One of the BBC receivers used for picking up the commentary from the launch *Magician* as she followed in the wake of the crews. Note that a regenerative detector – with no r.f. amplifier – followed by an audio amplifier, is used. The engineer is H. S. Walker of the Development Section.

In passing it should perhaps be mentioned that this was not the first running commentary from a launch following the Boat Race. In 1925 the Burndept Company transmitted from the launch *Etona* a commentary which was relayed over loudspeakers in the enclosure. But the BBC's was the first broadcast commentary on the Boat Race, and a huge success it was. *Wireless World* voted it an easy first among the O.B.s of the year. And Reith wrote to Eckersley: 'I want to put in writing my congratulations on the wonderful achievement of your Department in connection with the Boat Race. There is no doubt that it was a unique event in Broadcasting, but I believe also that it may well prove to have been the most outstanding technical feat ever brought about by any Broadcasting organisation. The BBC is prouder than ever of its Engineering Department, and this magnificent achievement must be of great encouragement to everybody.'

8 Relays

No account of the early activities of the BBC would be complete without some mention of the first attempts to relay programmes from abroad. Towards the end of 1923 A. G. D. West, aided by Baynham Honri, set up receiving equipment at Biggin Hill aerodrome, where a hut and an aerial had been put at his disposal by the Air Ministry. They began by trying to pick up American medium-wave transmissions, using a receiver having no less than twelve high-frequency stages. This was not a success. In West's own words, 'It gave us the Americans at full strength, but it gave us also all the Morse stations in Europe, practically every thunderstorm in the world, and a frightful amount of interference from the harmonics of high-power stations.' Fortunately, however, West had another string to his bow. The East Pittsburg station of the Westinghouse Electric Company, KDKA, was transmitting its programmes simultaneously on two wavelengths – 362 and 100 metres. West and Honri tried picking up the 100-metre transmission with a small set. Rather to their surprise they found that the shorter wavelength had distinct advantages. Atmospherics were not so deafening, and there was less interference from spark transmitters and from the harmonics of high-power C.W. stations. After a good deal of experimenting they settled on a circuit with six transformer-coupled r.f. stages, an anode-bend detector, and two a.f. stages.

During Christmas week a concerted effort was made to pick up KDKA on 100 metres and relay its programme. It was not exactly the ideal time to be keeping late-night vigils at Biggin Hill, for there was snow on the ground and it was bitterly cold. The first attempt at relaying was made on 22 December, but the atmospherics were so bad that they completely drowned the music. On Boxing Day results were no better – perhaps the fact that there was a blizzard that night had something to do with it. The following night a guy anchorage came adrift and one of the masts collapsed. But at midnight on Friday West and Honri were rewarded with success at last. The atmospherics had abated, and *A Song at Twilight*, followed by the overture 'Oberon' came through clearly from KDKA. The programme was relayed by all stations from midnight until 1 a.m., though West had to keep his hand near one of the tuning coils to prevent the set going into oscillation. Equally good results were obtained the following night, and all stations relayed KDKA again. In this fashion, nearly fifty years ago, West and Honri succeeded in bringing to listeners for the first time the sounds of American broadcasting. It is interesting to reflect now that the sunspot cycle was at minimum then, but of course the significance of this was not appreciated at the time. More American relays via Biggin Hill followed in 1924. In September 1925 the BBC's receiving station at Keston, only a few miles from Biggin Hill, was completed, and from then on all relay reception was done there.

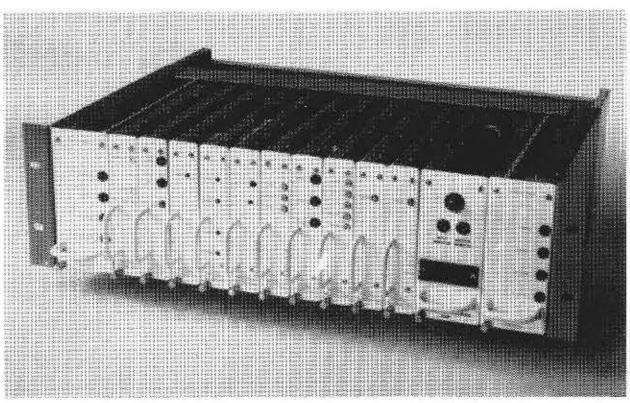
The first line relay from abroad took place on 31 December 1923, but it can scarcely be regarded as anything more than a stunt. After some difficulty a telephone line was connected through from the Radiola station in Paris to Savoy Hill. The BBC had hoped to broadcast a speech by the French premier, M. Poincaré, but in the event they had to make do with General Paul Antoine, President of the Radiola Company, instead. After his speech a Frenchman sang *God Save the King* and the programme ended with the singing of the *Marseillaise*. *Amateur Wireless* reported that the results were admirable, marred only by a little fading. All the same it is difficult to escape the conviction that with such a long length of submarine cable, and negligible equalisation, the programme, especially the singing, must have sounded pretty atrocious.

The next attempt came in March 1926. The speeches at the League of Nations were sent by landline from Geneva to Paris, then transmitted by the Eiffel Tower station and picked up at Keston. This attempt proved abortive, and another one in September was not much more successful. 'At 1.15 without warning the transmission from Geneva began. As on previous occasions it was loud, but very indistinct', reported *Amateur Wireless*. But the following year there was a measure of success. The ceremony of the opening of the Menin Gate on 24 July was relayed by line via Ypres to Ostend, and thence across the Channel by submarine cable. *Wireless World* commended the BBC. 'On the success of the Menin Gate broadcast the BBC deserves every congratulation . . . the broadcast was the most ambitious yet attempted by the BBC on the Continent.'

9 Postscript

The first five years of the 'BBC' (if we may take this to mean both the Company and the Corporation) saw broadcasting in Britain progress from a curiosity to an accepted part of our way of life. The programme policy which brought this about can be largely credited to the wise guidance of John Reith aided, perhaps, by the historical 'accident' of the General Strike. But public acceptance of broadcasting was also dependent on the dedicated thoroughness of Peter Eckersley and his staff – as well as the Post Office and the firms which co-operated with the BBC – in dealing with such basic engineering problems as strength of reception, and studio acoustics, and the quality of microphones, landlines, and modulation systems. The greatest tribute to the work of these early engineers is that the listening public (most of them using crystal sets and headphones) soon took the technical quality of the transmissions for granted, and directed the bulk of their comments and criticisms at matters of programme content.

Automatic Video Equaliser



In a complex television distribution-network, the video signal is subject to a number of types of distortion between the studio output and a transmitter input. These distortions cause random variations of the signal parameters; normally, the variations are of a magnitude which permits the more-significant distortions to be corrected by automatic devices operating on an Insertion Test Signal.

The automatic video equaliser has been developed in the light of an analysis of network performance and operational experience with an earlier equipment; it provides a means of automatically correcting distortions of the following:

- Overall signal-level
- Low- and medium-frequency bar-tilt (streaking)
- Pulse-to-bar ratio (loss of fine picture-detail)
- Chrominance/luminance gain inequality (saturation)
- Chrominance/luminance delay inequality (displacement of the colour components relative to the black-and-white components in a picture).

A digital control system provides sophisticated performance characteristics with a high degree of reliability. Conventional frequency equalisation is used for correcting low frequency distortions, and a transversal equaliser for correcting high-frequency distortions. In the event of the Insertion Test Signal being removed from the incoming signal, the amount of correction remains at its value when the ITS is lost.

Acoustic Modelling of Studios and Concert Halls

H. D. Harwood, B.Sc. and A. N. Burd, B.Sc., F.Inst.P.

1 Introduction

The study of room acoustics is not an exact science and it is not possible in the present state of knowledge completely to predict the acoustic properties of a music studio or concert hall from theoretical considerations. It is rarely practicable to copy existing successful designs exactly as site requirements and seating capacity are usually different and this means that each new design is a fresh challenge to the ingenuity of the acoustic designer.

Faults in the basic design which affect the acoustics of a building are not normally capable of correction after construction has started and even if some modification is possible it is likely to prove costly. Errors in acoustic treatment can usually be put right but the expense involved is considerable. For example, it is reported that over $2,000,000 have been expended in improving the acoustic properties of just one concert hall in America.

In these circumstances any acoustic aid to design which can be obtained is welcome and one which has considerable potential is that of acoustic modelling. This technique not only permits objective measurements to be made, such as impulse response and reverberation time, but also actually allows the sound of an orchestra to be heard as if it were in the real studio, thus permitting a subjective assessment of the sound quality before any building is commenced.

2 Basic Principles

In a medium such as air the wavelength of a sound is inversely proportional to frequency. Therefore if a model of a studio is made with a scale factor of k ($k > 1$), the following conditions will apply.

(i) The number of reflections per second at the surfaces will be increased in the ratio k

(ii) For similarity in what might be termed the 'geometrical acoustics' the sound wavelength must be reduced in the ratio $1/k$ to keep the ratio of wavelength to obstacle size the same. It follows that the frequencies must be increased by the factor k.

(iii) The air absorption should have a value k times that applying at normal frequencies since the path lengths are reduced by this ratio.

(iv) If the acoustic impedances of the surfaces of the model at the increased frequency range are the same as those of the corresponding surfaces in the full-size studio over the normal frequency range, it follows that the reverberation time will be reduced in the ratio $1/k$.

Thus if a recording is made of an orchestra playing under completely dead surroundings and reproduced from loudspeakers in the model at a tape speed k times that used for the original recording, the sound can be picked up by special microphones and re-recorded at the high tape speed. If this recording is now replayed at the normal tape speed, the acoustics of the model should correspond to those of the full-size studio and can be judged accordingly.

As a first step, it was decided to carry out a proving experiment and model an existing studio so that the results from the model could be checked against the results obtained in real life.

3 Instrumentation

3.1 Non-reverberant Music

In carrying out subjective tests for acoustic modelling it is necessary to use as a source, programme having no reverberation of its own. As no suitable material was available, arrangements were made in conjunction with the Building Research Station to record some orchestral music in their large free-field room. The English Chamber Orchestra and the Phillip Jones Brass Ensemble played various pieces which included excerpts from Mozart, Haydn, Wagner, Arnold, Gibbons, and Civil. In addition, a number of staccato chords were played to help assess the reverberation in the model. The recordings were made in stereo as it was desirable to hear as much of the acoustics of the model as possible.

3.2 Microphones

The microphones have to be capable of reproducing the full frequency range with an adequate signal/noise ratio. As a compromise between bandwidth required and size of model, a scale factor of 8 was chosen for the model.

The microphones therefore had to be capable of covering a frequency range from 400 Hz to 100 kHz. The only microphone capsule which would cover this frequency range at the time was a 6 mm omnidirectional capsule. The diameter is rather large for this purpose, being too directional at the upper end of the band, but it was already rather insensitive, so a smaller capsule was ruled out. The commercially available head amplifiers were too noisy for this purpose so one was designed to have a signal/noise ratio better by 15 dB, and having an input impedance of 0·3 pF in parallel with > 3000 MΩ.

As the microphones are nominally omnidirectional the spaced microphone technique had to be used for sound pickup.

3.3 Loudspeakers

The performance of the loudspeakers represents the most difficult part of the whole exercise. The sound output in conjunction with the background noise level of the microphones determines the signal/noise ratio from the model, the quality of reproduction decides whether any spurious colouration is added to the acoustic properties of the model, and the directional properties determine the ratio of reverberation to direct sound. As with the microphones, the frequency range is 400 Hz to 100 kHz.

The choice of directivity is a difficult one. To simulate successfully an orchestra many minute sound sources would be required, needing as many channels from the tape recorder to supply them; this is clearly not practicable in the present state of the art. Another suggestion which has been made is to use a very wide source to cover the whole orchestral width, but this would in practice be far too directional. The solution chosen was to simulate a monitoring type loudspeaker as this had the advantage that in the proving experiment real loudspeakers of this type could be used in a real studio and corresponding recordings made to check the results obtained from the model.

After much experimentation, a three frequency-band loudspeaker system was designed. The low frequency unit, 110 mm in diameter, was made of a vacuum-formed thermoplastic cone and operated from 400 Hz to 3 kHz. The middle frequency unit consisted of a commercial unit having a domed plastic diaphragm 20 mm in diameter and operated from 3 kHz to 21 kHz. The high-frequency end consisted of a cluster of forty-five electrostatic units, each 25 m in diameter, specially made for this purpose and mounted on the convex side of a copper hemisphere, thus giving a wide angle of radiation; they covered the frequency range 21 kHz to 100 kHz.

Equalisation was applied to the loudspeaker characteristic firstly to make the axial response/frequency curve uniform; this was then modified as the result of listening tests to yield the most natural sound quality. In conjunction with the microphone described earlier, a signal/noise figure of 60 dB was obtained.

3.4 Tape Recorder

This instrument had to cover the frequency range 50 Hz to 12·5 kHz at low tape speeds and the corresponding values of 400 Hz to 100 kHz when speeded up by eight times. The only type of instrument capable of meeting these requirements was an instrumentation machine but the signal/noise ratio was far too poor. Modifications were therefore made to improve this, but it remained the weakest link in the chain from this point of view, a figure of 52 dB being the best obtainable.

3.5 Model Reverberation Room

As explained earlier, it is necessary for the surfaces of the model to be covered with materials of the correct acoustic impedance. To ensure that this is so, it was necessary to construct a model reverberation room to measure this factor at the scaled-up frequencies. A model of a room to ISO standards was made of 12 mm-thick steel walls, with a roof of similar thickness made of Perspex so that the position of the measuring microphone could be observed.

In choosing materials for the model, similar textures were used whenever possible; thus the type of carpet and underlay used in the real studio was successfully modelled by a particular type of velvet and perforated absorbers were closely matched by their exact counterparts.

One factor which gave considerable trouble at first was absorption at high frequencies due to the air. This is dealt with in the next section.

3.6 Air Absorption

Sound propagation measurements in air at high frequencies have shown an attenuation greater than that due simply to viscosity and thermal conductivity. The extra attenuation has been shown to be largely due to a molecular relaxation absorption phenomenon in oxygen which is a function of the humidity. The excess absorption in the air in the model can therefore be eliminated by drying the air, a figure of 4 per cent relative humidity giving results closely comparable with a figure of 45 per cent R.H. in real life. Experiments to dry the air with silica gel were largely unsuccessful, and it was found necessary to use an artificial zeolite for this purpose. It was then possible to dry the air in the model in a matter of about half an hour, which compares very favourably with reported efforts in Germany which took several weeks. The model reverberation room only took a few minutes to dry.

3.7 Model Orchestral Personnel

The studio is rarely used for solo instruments, and when a full orchestra is using it, the presence of so many persons appreciably affects the reverberation; it is therefore necessary to model them too. Various estimates of the absorption due to persons have been made, some for closely packed audiences, others for individual persons. An orchestra fits into neither of

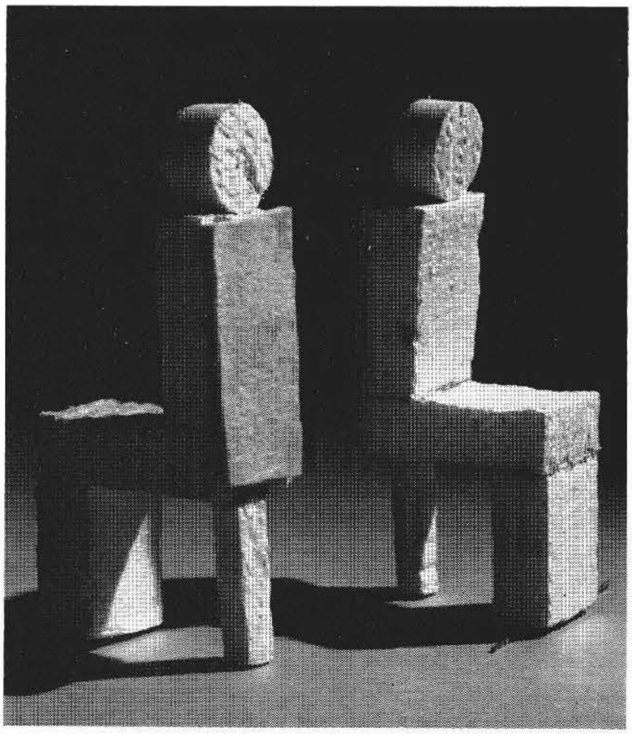


Fig. 1 Expanded polystyrene 'musicians'.

these categories, and it was necessary to measure in a reverberation room the absorption due to persons sitting the right distance apart. Subsequently model orchestral players were designed with the help of the model reverberation room to yield the corresponding absorption in the model. They were made of foamed polystyrene, cut approximately to the shape of a seated player, and had a piece of 3 mm thick felt stuck to their backs. The appearance is shown in Fig. 1.

4 Proving Experiment

4.1 General

The principles of acoustic modelling, as outlined earlier, are fairly simple, but the practical implementation of them is another matter. The studio chosen for the proving experiment, Maida Vale No. 1, is the main orchestra studio, and it was selected partly because changes to it were being considered. If the experiment were successful these changes could be modelled prior to engaging in expensive building work. A view of the completed model is shown in Fig. 2, together with an early model two-frequency-range loudspeaker.

4.2 Reverberation Time of the Model

The reverberation time of the real studio is determined by the absorbing elements. Data exists on most of these, but the effect of the ceiling which resonates at about 150 Hz was a more difficult problem and had to be computed. Corresponding absorbing elements for all these items had to be designed for the model studio with the help of the model reverberation room.

The resulting equivalent curve of reverberation time as a function of frequency in the empty model was within ± 10 per cent of that of the real studio, a satisfactory result considering all the assumptions. The predictions of studies reported in the literature suggest that in any case this degree of difference should be inaudible in practice.

4.3 Tonal Quality

The tonal quality was tested by replaying the stereo tape of non-reverberant music over two monitoring type loudspeakers in the real studio as well as in the model. It may be argued that this test does not closely simulate an orchestra and this is true,

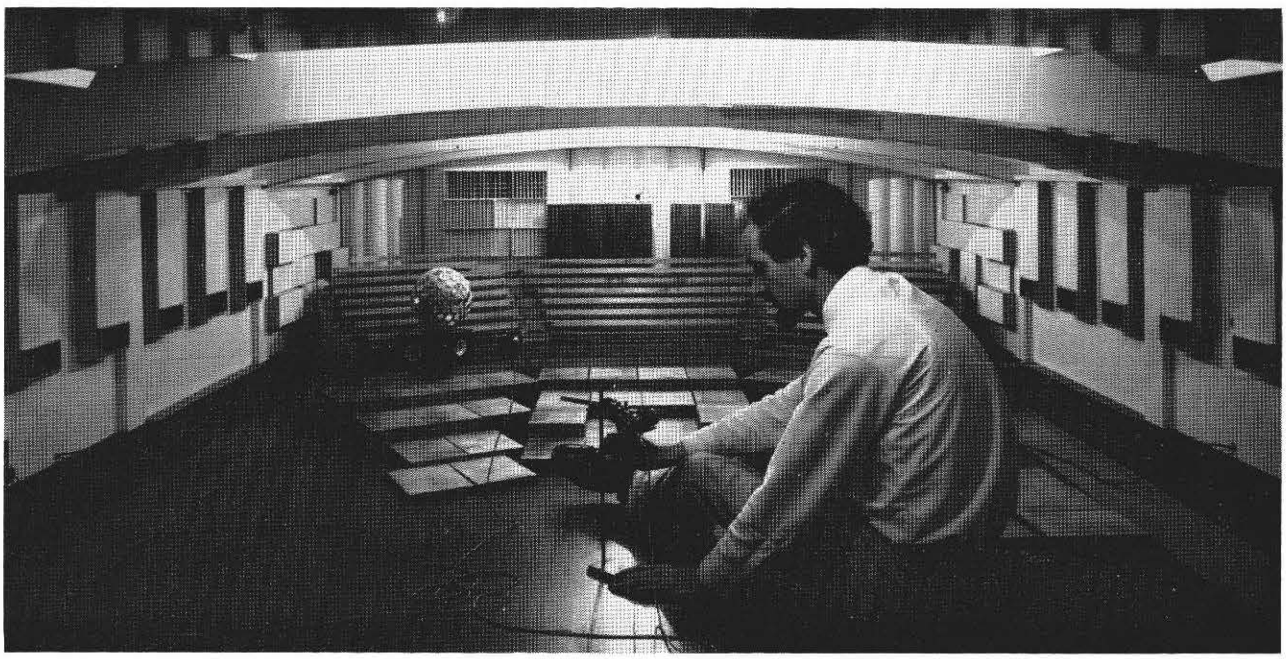


Fig. 2 An engineer in the completed model of Maida Vale No. 1 Studio.

but the high degree of similarity in the two cases fits in well with the idea of a proving experiment.

In the first instance, the studio was used empty and in turn a pair of BBC monitoring loudspeakers type LS 5/5 and also type LS U/10 were used to allow the effect on quality of the differing types of loudspeaker to be assessed. The sound was picked up by omnidirectional microphones spaced 5 m apart and − 10 dB of cross-mix was employed.

The recordings thus obtained were compared with those from the model and a satisfactory degree of similarity was observed. Persons who knew the studio well complained, however, that in neither case was the sound representative of that from the studio in normal use, i.e. with a large orchestra. The complaint was not so much of the degree of reverberation, which was expected to be longer, as of the tonal quality itself, particularly of the strings.

Further recordings were therefore made in the studio with about seventy members of the choir sitting in place of the orchestra. The resulting quality was indeed found to show a tonal change compared with that from the empty studio, the strings sounding appreciably more wiry – a change which could neither be predicted from the absorption characteristics of the orchestra, nor measured objectively.

The recordings in the model were therefore repeated using the model musicians already described, and on replay it was evident that the change in tonal quality had also been obtained in this case, thus fully justifying the modelling technique. This also points to the usefulness of modelling in the present state of ignorance of how, or even what, to measure in order to determine the subjective aspects of acoustics. It is still essential to listen to the sound quality in addition to measuring such parameters as we are able.

5 Applications

In view of the success of the proving experiment it was decided to extend the technique by testing various experimental changes to the studio with a view to assessing their value in improving the acoustics. Modifications tested consisted of:

(*a*) mounting mid- and high-frequency absorbent on the end wall behind the orchestra in order to reduce the possibility of flutter effects;

(*b*) mounting wideband absorbent on the ceiling, which is relatively low, to reduce the effect of early reflections;

(*c*) placing a canopy over the orchestra, the canopy being flat or curved and at various angles;

(*d*) covering the ceiling with a reflecting material to remove the effects of the absorption around 150 Hz;

(*e*) removing the step construction of the choir seating by covering the area with a smooth reflector;

(*f*) removing the choir seating altogether and placing the orchestra nearer the end wall, and finally

(*g*) by replacing the orchestral rostra and choir seating with a new design suggested by Pierre Boulez.

In modifications (*a*) and (*b*) various amounts of absorbent were tested and the quantity and position were adjusted to give the optimum results.

In each case, in addition to the reverberation measurements, listening tests were carried out comparing a tape of the test condition with that of the studio unaltered. The fact that the programme source is identical in all cases makes comparison much easier than if an orchestra had even played the same piece in the real studio under the various conditions. Apart from the time lag which would, of course, be inevitable, and thus make comparative judgements more difficult, no fewer than forty variations were examined, which would represent a prohibitive cost in real life. For example, the cost of the curved canopy alone would be of the order of £1000 and when installed would be very difficult to adjust in angle without considerable further expense; this is to be set against the fact that the model showed it to have very little beneficial effect.

One factor which these tests have shown up is the need for some general agreement on the individual qualities which are essential to assess the overall sound quality of a studio accurately and completely.

6 Conclusions

Tests have been carried out to determine the accuracy with which it is possible to model a studio. In the event an unusual effect was found which demonstrated that the degree of success achieved was unexpectedly high. The usefulness, both from the economic and research aspects, of this technique has been shown. Further work needs to be carried out to determine just what properties are necessary to describe the sound quality of a studio completely.

BBC Engineering 1922 – 1972

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1 Co-operation

A recurring theme in the history of BBC engineering is co-operation; between those who create programmes dedicated to 'information, enlightenment and entertainment' and the BBC engineers who bring them into people's homes; between those engineers and the firms that produce most of the hardware they use; between those same engineers and the receiver manufacturers, the radio retailers, the Press, and the public; and between engineers in many countries faced with the same problems and with the complex task of exchanging programmes between different parts of the world. Co-operation is also important with the Post Office on the provision of circuits and with them, and recently the Ministry of Posts and Telecommunications, on the allocation of frequency channels. Broadcasting is unique in its dependence on the interweaving of all these strands, and its success in this country owes a great deal to the recognition of this interdependence. True, there have been moments of strain; in the early days programme producers and engineers tended to underrate each other's expertise, there was a time when the BBC considered the Post Office to be too jealous of its monopoly of communications, the industry has sometimes thought that the BBC took too large a share of development work, and the public has not always been willing to accept the limitations imposed by technical facts. Nevertheless, the history of BBC Engineering has been one of steady progress punctuated by moments of brilliance, and the cross-fertilisation of ideas between all the diverse parties has benefited all of them.

2 Operational and Specialist Engineering

We are cheating a little in celebrating the jubilee of BBC Engineering now, because P. P. Eckersley did not become the Chief (and only) Engineer of the British Broadcasting Company until 5 February 1923. But (as Peter West has recounted) when the Company took over the business of broadcasting on 14 November 1922, it already had a transmitter working in London and on the following day it took over two others in Birmingham and Manchester. These transmitters had been set up as experimental broadcasting stations by three of the major companies that were among the founders of the Company, and in March 1923 the BBC began to recruit its own engineers to take over the running of the stations. By the end of that year there were nine stations in operation, eight of them with their own studios. Problems of studio equipment, acoustics, and radio propagation were already looming and it was evident that much development work would have to be done. Its importance was recognised by the appointment of Capt. A. G. D. West, who had worked with Rutherford at the Cavendish Laboratory, as Assistant Chief Engineer (Development) in 1923 and by H. L. Kirke's appointment as Senior Development Engineer in February 1924. The split between the operational engineers who keep the service going, and the specialist engineers who are responsible for new installations and developments, had already occurred.

Let it not be thought, however, that all the ideas came from the specialists; the operation of temperamental microphones and oscillation-prone amplifiers, the rigging of outside broadcasts in difficult situations, the maintenance of new types of equipment, and the repair of storm damage to aerials, often demanded ingenious improvisation. The operating staff in the studios and at O.B.s were nearest to the source of programmes and best able to appreciate the needs and aspirations of producers. Some important developments can be traced to their initiative; the transition from 'dead' to 'live' studio acoustics in the 1930s, the design of light portable O.B. equipment, and sound recording equipment just before and during the war respectively, the transformation of sound programme techniques to include stereo in 1966 and to satisfy the present demand for music with a special sound rather than faithful reproduction, and many developments in television resulting from the ever-increasing sophistication of programme presentation and from the addition of colour.

Naturally the most fundamental inventions and applications have come from the specialist departments. Statistics show that over the years BBC engineers have been responsible for 350 patented inventions and have contributed some 300 papers, many of them describing important development work, to professional societies. More important than the statistics is the vast range of new equipment that has been produced for the broadcasting service – some designed and made by the BBC itself, some manufactured by the industry to BBC designs, some produced by the industry to BBC specifications, and some produced for the commercial market and, where necessary, adapted to BBC requirements. Sometimes the BBC's needs have been ahead of industrial output; in 1926 BBC engineers had to design the first 30kW m.f. transmitter (5GB at Daventry, the prototype for the Regional scheme) and they also produced v.h.f. and u.h.f. transposers and successive generations of crystal drives and of studio, O.B. and disc-recording equipment.

3 Studio Development

Studio equipment and techniques were advancing rapidly when the Corporation took over from the Company at the beginning of 1927. With the improvement in microphones the old heavy draping gave place to building board and 'felt-and-wallpaper' treatment, though it was not until 1933 that a really lively acoustic (achieved by the use of bare wood and later of membrane absorbers) began to be accepted. The techniques of balance and control were worked out after the appointment of R. Haworth as Programme Liaison Engineer in 1926 – though not without sharp divergencies of opinion between programme staff and engineers. Continuity working, in which the outputs of all programme sources in a nationally-networked programme are routed through one central control position before being distributed to the transmitter, was introduced in the External Services during the war and in the Radio Services just after it; but it did not become possible in television until 1955, when the improved performance of vision circuits made it possible to send programmes from Scotland to London and back again without appreciable degradation.

Wiring is mostly behind the scenes, but highly important. In 1924, heavy wire of 10A capacity gave place (apart from power-supply wiring) to lead-covered cable containing one pair of 10lb per mile conductors, which was heavy and unwieldy. The S.B. (Simultaneous Broadcast) board at Savoy Hill had to be moved twice, all the re-wiring being done by control room staff working at night – braced by supplies of sandwiches and beer but without benefit of overtime payments. Multi-pair cable began to be used instead of the cumbrous '1 pair 10' in 1939.

4 Simultaneous Broadcasting

At first the programmes were programmed independently from local resources – hence the early interest in O.B.s. The first attempt at simultaneous broadcasting was made in 1923 and caused a considerable stir. Open-wire telephone lines, hired from the Post Office, were the only means of programme transmission. They were prone to storm damage and noise, but they provided two-way channels and were used both for programmes and for telephone communication. An elaborate relay-switching system was developed to enable the lines to be taken over for service messages, or by PBX, when not carrying programmes. Telephone cables were being installed all over the country by the Post Office from 1926 onwards, and specially screened and loaded music circuits in cables were introduced in 1931. The testing and equalisation of these circuits was a major task for the BBC in the 1930s. The introduction by the Post Office of carrier systems for telephony brought new problems for BBC Lines Engineers during the war. In 1950 the first coaxial cable, between London and Birmingham, became available for vision transmission, and in later years s.h.f. links came into use. Considerable economies in line rentals were made by using direct pick-up of BBC stations wherever possible. The introduction of Eurovision, based on standards conversion, in 1954 and the start of satellite communications with Telstar in 1962 extended the area from which television programmes could be taken until it embraced every continent.

Switching was a problem almost from the start. Even when there was only one radio programme, several sources (studios and O.B.s) had to be switched into it. At first double-pole porcelain-based knife switches were often used, but plugs and jacks were already taking their place in 1923. With the increasing complexity of the system the arrays of cords in control rooms began to resemble cat's-cradles. Already in 1929 an attempt was made to introduce automatic switching of programme circuits in Manchester. The equipment gave a great deal of trouble because the selectors, though well-proven in telephone exchanges, were not designed to satisfy the more exacting requirements of broadcasting. However, relay switching was a success at Bush House during the war, and rotary switches came into use in 1951 for programme routing and later for sequential monitoring. Methods of switching were transformed by the introduction of solid-state devices, culminating in the video-switching matrix of 1968.

5 Growth of the Transmitter Network

In the early days the greater part of the effort available for development and planning went into the transmitting stations. The Regional scheme for national coverage of two radio programmes started with the building of four high-power dual-transmitter medium-wave stations, which were opened between 1929 and 1933. The 25kW long-wave transmitter at Daventry, later replaced by Droitwich, was already working in 1925. During the war there was great activity in building transmitting stations for the External Services, including Ottringham (1943), then the most powerful broadcasting station in the world (800kW). The network of v.h.f./f.m. stations and the v.h.f. television stations (completed in 1970) belong to recent history, with the twenty v.h.f. Local Radio stations opened between 1967 and 1971. The current programme of transmitter building provides for some fifty-five high-power u.h.f. television stations (initially carrying three programmes) and several hundred relay stations – a heavy commitment both for the BBC and for the industry.

Broadcasting in the h.f. bands to audiences overseas started experimentally in 1926. Amateur radio operators had pointed the way by establishing world-wide contacts on the then-despised short waves; several of the best-known amateurs joined the BBC staff. Experiments in ionospheric sounding had established the refractive properties of the ionosphere in 1924 (though top-side sounding did not become possible until the satellite era). The Empire station at Daventry opened with two transmitters in 1932, and the short-wave services developed enormously during the war – taking advantage of the methods that had been developed for determining the optimum working frequencies for each path at different times and seasons and in different phases of the sunspot cycle. In recent years the availability of relay stations overseas (some operated by the BBC and some by the Diplomatic Wireless Service) has greatly improved the effectiveness of the External Services.

6 Recording

The first attempt to broadcast a gramophone record was made in 1925, using a hornless acoustic gramophone placed near the microphone. For some years after the introduction of electrical pickups, records were used to fill gaps in the programme rather than for their intrinsic interest. There was no great incentive for the BBC to record its own programmes, because there was a feeling (still shared by many people) that live broadcasting was real and recordings were somehow not quite genuine – though of interest for the archives. The start of regular short-wave broadcasting in 1932 made recording imperative, because programmes had to be repeated successively for the various time zones. The first recording of a broadcast had been made by a commercial firm; it was the opening of the British Empire Exhibition at Wembley by King George V in 1924. But the BBC itself had no recording equipment until it hired a Blattnerphone magnetic recorder in 1931. The much-improved Marconi-Stille tape equipment, the Philips-Miller film system and the MSS direct disc recording, equipment followed each other in quick succession and were all brought into service in 1935–6. Then came the BBC's own mobile disc recorder, the type D static recorder of 1945, which could operate at either 78 or 33⅓ r.p.m. After the war, there came the great advance in tape recording when the German Magnetophon, with h.f. bias, became available. Disc recording flourished alongside tape and there were great improvements in disc-reproducing equipments and in the quality of the output. Radius compensation was the subject of a BBC patent in 1934; the TD/7 desk followed in 1935, and the DRD/1 in 1952. Both were capable of reproducing records as well as direct-recorded discs.

7 Some Engineering Achievements

It says much for the foresight of those responsible that some of the most useful tools the BBC has ever produced became available just at the moment when they were most needed; The OBA/8 equipment (1938), which was the mainstay of studios (as well as O.B.s) throughout the war, being designed to work either from batteries or from the mains, the type C disc recorder (1940) and the PER/3 portable equaliser-repeater (1938). All these proved to be of sound design and they remained in service for many years.

Some of the processes involved in broadcasting demand a high degree of precision. Nowadays the timing of pulses and electronic switching is measured in nanoseconds. Even in 1924 the frequencies of transmitters were controlled by tuning forks to an accuracy of $\pm$ 1 part in 10^5; by 1967 a rubidium gas cell had increased the accuracy of the 200kHz transmissions from Droitwich to one or two parts in 10.[11] The grinding of sapphires to form styli for disc recording demanded extreme mechanical precision in 1941, and so did the traction mechanisms of telecine and telerecording machines in the 1950s.

These developments are traced at length in a book to be published by the BBC in connection with its fiftieth anniversary, which falls on 14 November 1972. Among the many other achievements of BBC engineering traced in this book (which has the same title as this article) are:

Acoustics
Refined methods of making acoustic measurements, including the phase-coherent pulsed-glide system and, more recently, the use of scale models, have led to improvements in studio design and acoustic treatment.

High-quality Loudspeakers
Each of a succession of high-quality monitoring loudspeakers has been recognised in its day as being among the best available.

Microphones
The type A ribbon microphone (introduced in 1934) and its later modifications were never bettered for performance by any other ribbon microphone, although they were superseded in 1955 by the smaller and lighter PGS. The L1 noise-cancelling lip microphone of 1951 set new standards of performance for a commentator's microphone.

Transmitting Aerials
Developments in this field were concerned with mast radiators, h.f. arrays, slot aerials (1949), feeders and feeder-switching, anti-precipitation aerials for rebroadcasting, and receiving aerials for technical monitoring and for programme monitoring.

Circuit Developments
These included a cathode-follower circuit introduced in 1938 and several types of modulator.

Line Equalisation
The need to use telephone circuits to carry broadcast sound programmes – and even video signals over short distances of a mile or two – inspired much pioneering work on equalisation.

Frequency Measurement and Stabilisation
In addition to the work done on transmitter drives, the needs of the Tatsfield receiving and frequency measurement station inspired development of high-stability oscillators, frequency dividers, and multipliers.

Specialised Measuring Equipment
The peak programme meter, which was introduced in 1938, is still accepted by many broadcasting organisations as the standard operational sound level monitoring device. Many other specialised types of measuring equipment have also been developed.

Volume Compressors and Limiters
Limiters were originally used primarily to protect transmitters from accidental overloads, but are now often also used as compressors. BBC designs have evolved to meet these changing needs.

Video-tape Recording
The BBC longitudinal video-tape recording system, VERA, was demonstrated publicly in 1958, but was soon afterwards superseded by the Ampex equipment.

Film Telerecording
The first transmission of a television programme recorded on film was in 1947, more than a decade before video-tape became available. Earlier telerecording systems sacrificed all the lines in each alternate field to allow time for film pull-down in the camera. After unsuccessful attempts by a film camera manufacturer to develop a 35mm film traction mechanism which would complete the pull-down during a field blanking period (about 1·4ms), a very successful 35mm system was evolved in which the camera shutter remained open throughout all but the top thirty lines of each field. This left only the remaining sixty lines of the picture to be exposed by phosphor persistence. Even in these days of video tape, some programmes are still recorded on 16mm film for sale to other broadcasting organisations.

Standards Conversion
The BBC pioneered standards conversion – which made Eurovision as well as other international live programme exchanges possible – in 1952, using a television camera looking at a picture displayed on a tube with a long-persistence phosphor. They also introduced most of the subsequent developments in standards conversion, including electronic line-store conversion (1963–4), and electronic field-store conversion (1967–8).

Improved Transmission of Colour Films
By carefully calculated cross-coupling between red, green, and blue channels of a telecine, the so-called TARIF (Television Apparatus for the Rectifying of Indifferent Film) equipment, introduced in 1965, made it possible to televise colour films with a colour fidelity comparable to the best obtainable from television cameras.

Television Electronic Effects
Inlay and overlay were introduced in 1953. The latter became much more effective when it became possible to use colour separation overlay. The electronic character generator ('ANCHOR') of 1970 produced clear letters and figures resembling print – not indecipherable hieroglyphics such as are printed on cheques.

Channel-saving Devices
The Sound-in-Syncs. system of 1969 made it possible for a 625-line television link to convey a high-quality sound signal as well as the picture signal by introducing a pulse-code-modulated signal during the line synchronising interval. Although this system can operate reliably on links with performances well below the acceptance limits for permanent United Kingdom circuits, the levels of noise and multipath distortion on some temporary and long-distance links are so severe that it became necessary to develop an alternative 'ruggedised' system which can operate on these poor-quality links at the cost of some reduction in audio bandwidth and signal-to-noise ratio. Other channel-saving arrangements have included methods of deriving communication channels from programme circuits.

Pulse Code Modulation in Sound Links
Coding and companding systems have been developed for sending high-quality sound signals over the Post Office wide-band multi-channel p.c.m. network. These links are particularly valuable for relaying stereophonic programmes, since the difficulty of maintaining a sufficiently low group-delay difference between the left-hand and right-hand signals disappears when both signals can be sent over a common circuit.

Miniaturisation
Printed circuits, solid-state components and integrated circuits have been fully exploited in the design of highly complex apparatus in compact form and with low power consumption and low heat dissipation.

Propagation
Experiments and theoretical studies of radio propagation are carried out in all the bands used for broadcasting, and the results are applied to frequency planning and the quest for spectrum economy.

Automatic Monitoring and Control
Automation has been applied to the monitoring, control, and switching of equipment, including unattended transmitters and transposers and 'self-operated' studios, and has enabled all the radio and television stations now in service to be operated with fewer staff than were needed in 1963.

Computers
Computers are being used for stock control, management information, the allocation of resources, and for technical studies such as the computation of service areas.

8 Major R. & D. Assignments

Two of the most formidable tasks ever undertaken by the BBC in the R. & D. field were the trials to establish the relative performance of 405-line and 625-line television systems in the v.h.f. and u.h.f. bands (1957–8) and the long series of tests to assess the relative performance of the NTSC, PAL, and SECAM colour systems (1962–3). Such trials would have been exacting if confined to the laboratory, but they were in fact concerned also with the more difficult task of comparing the systems in the various conditions in which viewers would actually see the pictures.

The whole of the BBC's expenditure on R. & D. amounts to less than 2 per cent of its total income. Much of it is directed towards savings in running costs, such as those achieved by the introduction of unattended transmitters.

9 Retrospect on Fifty Years

How far has BBC Engineering come in fifty years? In November 1922 there were three 1kW transmitters, carrying independent programmes and with an audience of a few thousand people, mostly equipped with crystal sets. The total staff of the Engineering Department a year later numbered forty-six. In 1972 nearly 600 transmitters carry two television programmes in colour and five radio programmes to the audiences in this country and programmes in forty languages to listeners overseas. The production and presentation of programmes has advanced from the use of a single microphone (the first sound mixer appeared about 1925) to the most complex radio and colour television programmes with live contributions from every continent. Some 7000 engineers, technical assistants, draughtsmen, craftsmen, and clerical and secretarial staff, are employed on the technical side, including those now attached to the three Programme Directorates.

Yet, looking back one is constantly surprised to find how long ago some of the techniques originated; water-cooled transmitting valves in 1922, the first O.B. (from Covent Garden), the first S.B. link-up, and the first relay from Paris, all in 1923, a broadcast from an aeroplane in 1925, the establishment of the BBC receiving station (at Keston) also in 1925, artificial reverberation in 1926, still picture transmissions (from Daventry) in 1928, regular thirty-line television transmissions in 1929, televised pictures of the Derby in 1931, and the high-definition television service in 1936. A great deal of engineering effort has been devoted to the great building programmes that have punctuated the BBC's history: Broadcasting House was opened in 1932, its Extension in 1961, Regional Centres in the 1930s, the Television Centre in 1959, the Birmingham Broadcasting Centre in 1971, and transmitting stations, with their imposing towers and masts from the first dual-programme station in 1929 to the u.h.f. television stations from 1964 onwards.

Six major projects have probably had the most direct impact on the public. Three of these have already been mentioned; the Regional radio scheme started in 1929, 405-line television in 1936, and 625-line u.h.f. television in 1964. The others were the start of v.h.f./f.m. broadcasting in 1955, stereophony in 1966, and colour television in 1967. Each of these has necessitated a great deal of planning, the preparation of specifications, the supervision of construction and installation work, and consultations with all the interests concerned in making British Broadcasting the splendid success that it has undoubtedly been.

The evolution of technology proceeds by occasional sudden mutations, followed by trial, adaption, and development. Among the great mutations have been the invention of the three-electrode valve (1906), the discovery of the properties of the ionosphere (1924), pulse techniques (invented in the 1930s and developed for radar during the war), the magnetic recording of speech (1924), the transistor (1948), and digital techniques (in the 1960s). BBC engineers were not responsible for the original discoveries, but they seized them avidly and displayed great ingenuity in applying them to practical needs. In so doing, they used sound engineering principles and insisted on the highest standards of performance consistent with reliability and economy.

Concepts are as important as equipment. The concept of bringing sound programme signals to a standard level at a predetermined point in each control room arose in 1923 and the traditional form of the broadcasting chain with A, B, C, and D amplifiers took shape then. The concept of continuity working was adumbrated just before the war. The concept of electronic scanning goes back to 1908 and that of the television waveform, almost in its present shape, was applied to the 405-line system by the EMI team in 1934. The concept of multiplexing signals so as to achieve compatibility by transmitting additional information which existing receivers can ignore was applied in the USA to the NTSC colour system in 1953 and to stereo broadcasting in 1962. The concept of interpolation was applied to the series of BBC electronic standards converters from 1963 onwards. The mathematical concept of processing signals as functions of time rather than of frequency was applied to the time-derivative equaliser in 1953.

Developments in the BBC have perforce been influenced by events outside. The General Strike of 1926 showed the importance of broadcast news at times of crisis and led to technical measures that faintly foreshadowed the precautions that would have to be taken in war-time. The war itself changed the face of broadcasting in this country. Television was stopped for seven years. Medium-wave transmitters could operate at first only in synchronised groups. There were immense problems of dispersal. By 1940 the principal emergency centre, Wood Norton, had become one of the largest broadcasting centres in Europe. Other centres were set up in many provincial towns and innumerable church halls were pressed into service as studios. At Bristol, the Clifton Rocks Tunnel provided a safe haven for a recording centre. The setting up of so many emergency control rooms, the provision of drives for new frequencies, the building of high-power stations for the External Services, and the equipment of the War Reporting Unit, made a heavy strain on depleted resources of manpower. Training had to be stepped up, young men were recruited before their call-up for military service and women Technical Assistants were taken on with great success. Materials and components were also scarce; equipment imported from the USA under lease/lend helped to fill the gap, but deliveries were uncertain because of losses at sea.

The planning of projects for the post-war expansion of BBC services has often had to be based on inadequate data; sometimes on little more than guesswork, and sometimes on sheer faith. Examples of these three categories are the Television Centre, the post-war communications scheme, and Eurovision respectively. Yet all met the requirements remarkably well and succeeded beyond expectations.

The operations and maintenance departments and the specialist departments are complemented by engineering services; personnel, training, information, and liaison. The administration of engineering staff was put on a firm basis by the appointment of P. A. Florence as Engineering Establishment Officer in 1935. The Engineering Training Department was set up in 1941 and transferred to Wood Norton in 1946. It has played a vital part in training technical staff, not only for the BBC but also for many broadcasting organisations abroad. The need to inform the public on reception problems and to counter electrical interference was already felt in 1923, when Eckersley mounted a campaign against 'oscillation'. Technical relations with broadcasters abroad were conducted by L. W. Hayes from 1927. Assistance to the developing countries by seconding experienced engineers to them reached a peak in the late 1940s when many of them were developing their radio services and again in the 1960s when they were setting up television services.

The history of engineering in broadcasting naturally dwells on the achievements of the pioneers. But development has been so continuous that there have been pioneers in every epoch. If a new survey is made in the year 2022 it will chronicle the achievements of many more of them in 1972 than there were in 1922 and will find that they were no less devoted to the ideal (if we may use that out-moded word) of public service and as adventurous in seeking out new paths in uncharted territory.

Earth Fault Test Apparatus (EFTA)

In television studios it is usually important to ensure that the metal framework of all sound equipment, such as microphone stands, do not come into contact with metalwork of mains-operated equipment such as lanterns, picture-monitors etc. This is necessary because the mains-earth wiring system may be carrying currents due to minor faults or switching transients which would cause objectionable noises in the sound output. To prevent this interference, the whole sound-equipment earthing system is kept entirely separate and the connection to ground made at one point only via the 'technical earth' cable (see Fig. 1).

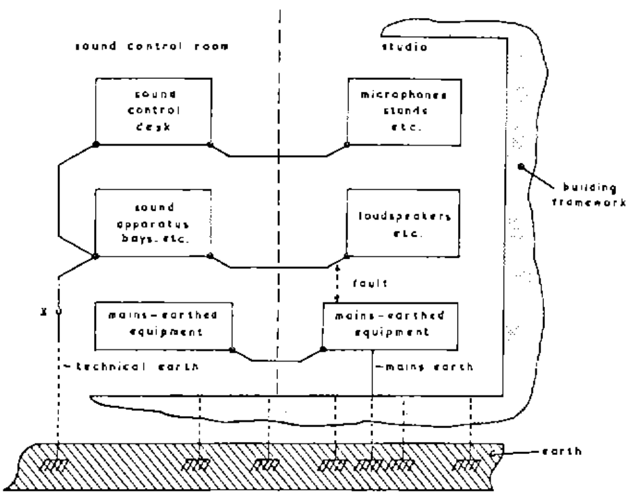


Fig. 1

During the period when all classes of equipment are being rigged in the studio, it is unusual for the sound output to be monitored. Accidental contacts between the earth systems may therefore occur without becoming evident until much later, when rehearsals commence, and it can then be very difficult to locate the fault in the full assembly of equipment rigged in the studio. There have been previous attempts to devise a system which would give an alarm immediately such a fault occurred, so that it could be readily traced on the few items of equipment being rigged at the particular moment. The apparatus devised for this purpose required that the technical-earth cable should be open circuited (point X, Fig. 1) during the rigging period, thus creating a safety hazard; also, the alarm facility was lost during operational hours, when it was necessary to by-pass the unit.

The apparatus now being demonstrated avoids the need to open circuit the technical-earth cable and can remain in operation continuously. A toroidal core carrying several windings permanently surrounds the technical-earth cable. One winding, L1, is tuned to form a very high-Q circuit resonating at 5 kHz, and when this is connected as in Fig. 2 a stable 5 kHz oscillation is established. The presence of the oscillation is monitored by a detector amplifier feeding appropriate alarm circuits.

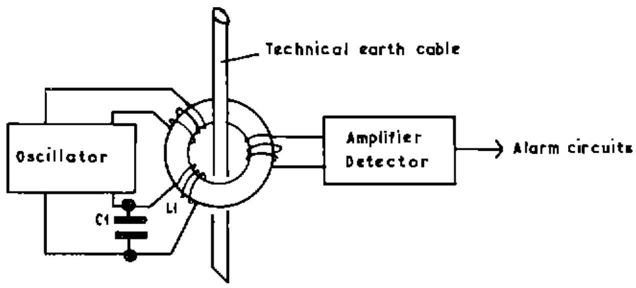
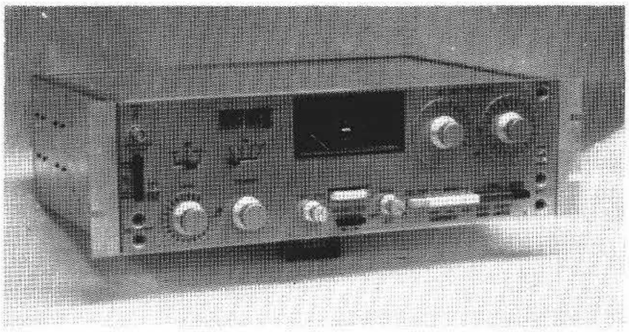


Fig. 2

The technical-earth cable, passing through the toroidal core, acts as another winding and, when a fault exists between the sound equipment and any other earthed metalwork, behaves as a short-circuited turn and severely damps the tuned-circuit. The oscillator is so designed that the decrease in Q of the tuned-circuit causes oscillation of output from the detector amplifier. The device is currently the subject of a Patent Application.

Audio-frequency Test Equipment EP14/1



This instrument is being developed to provide comprehensive test facilities for audio-frequency apparatus. It will occupy a single housing, suitable either for bay-mounting or for portable use in a carrying-case containing also the necessary batteries.

The equipment comprises an a.c. test-meter and variable-frequency tone source; these are separate electrically, except when connected for the calibration of the tone source, as described below.

The a.c. test meter will accept input signals at levels ranging from −81·5 dB to +20 dB, and can be switched to present an input impedance of either 600 Ω or 50 kΩ. The following modes of operation are available, selection being by means of push-buttons:

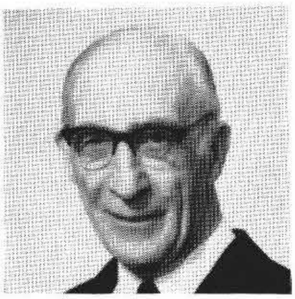
1. *Calibrate:* The mean-level indicating-circuitry is switched internally directly to the tone-source.
2. *Mean:* The mean-level indicating-circuitry is switched to the input connector via attenuation variable in 10 dB and 0·5 dB steps, giving a measuring-device with a uniform frequency-response (±0·1 dB 20 Hz–20 kHz, −3 dB ±3 dB at 5 Hz and 50 kHz).
3. *Harmonics (100 Hz):* As 2, but with a high-pass filter interposed, having a 150-Hz 3 dB-point and giving at least 60 dB loss at 100 Hz.
4. *Harmonics (1 kHz):* As 2, but with a high-pass filter interposed, having a 1·5 kHz 3 dB-point and giving at last 60 dB loss at 1 kHz.
5. *Peak:* A standard TPM circuit, with response uniform from 20 Hz to 20 kHz, is switched to the input connector via the variable attenuation.
6. *Weighted TPM:* As 5, but with CMTT weighting-net work interposed.
7. *Noise:* A quasi-peak-reading circuit of new design is switched to the input connector via the variable attenuation and the CMTT weighting-network.

A single meter is used as the indicating-device for all modes of operation; three scales are provided for the measurement of level, modulation peaks and noise.

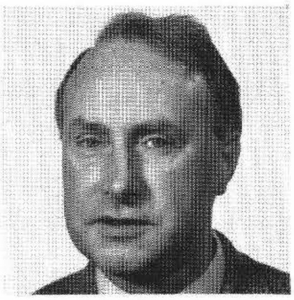
The tone source has a frequency-coverage from 5 Hz to 50 kHz, in four switched ranges. 600 Ω balanced, 75 Ω balanced, or 75 Ω unbalanced output-circuit connections can be selected by means of push-button switching, and a separate balanced output connection is provided for monitoring; the output from this is available for all the modes of operation listed above. The balanced main output-circuit modes give an output level of +20 dB into a 600 Ω load with a frequency response uniform within ±0·1 dB from 20 Hz to 20 kHz. The unbalanced mode gives an output level of +6 dB into 600 Ω load with a frequency response uniform over the entire range of the oscillator. Attentuation of 60 dB in one step of 20 dB and one of 40 dB, and of 40 dB in 2 dB steps, is provided, giving a total available attenuation of 100 dB.

When the instrument is feeding tone to a high-impedance load, a 600 Ω terminating-resistor can be switched to the output connector to ensure correct operating-conditions for the tone source.

Biographical Notes



Edward Pawley joined the BBC Lines Department in 1931 after studying at Imperial College, London, and working for five years with the International Standard Electric Corporation where he developed a life-long interest in the international aspects of telecommunication. He was transferred to the Overseas and Engineering Information Department in 1935, became Head of Engineering Secretariat in 1942, Head of Engineering Services Group in 1950 and Chief Engineer, External Relations, from 1965 until his retirement in 1971. He served on various committees concerned with electrical interference and standardisation and was Chairman of the Technical Committee of the European Broadcasting Union from January 1953 to December 1970.



Dudley Harwood is a graduate of London University and joined the BBC Research Department in 1947 after spending some years in the Acoustics Section of the National Physical Laboratory. He has worked on problems associated with microphone and loudspeaker design and development, and on the determination of factors involved in the engineering and subjective aspects of stereophony. He is at present responsible for the work on acoustic modelling and is also engaged on questions relating to quadrophony. He has published a number of monographs and other papers and has taken out a number of patents.

Alec Burd joined the BBC Research Department in 1955 having qualified in Physics at Liverpool University. In 1969 he became a Fellow of the Institute of Physics. He served for six years as the Honorary Secretary of the Acoustics Group of the I.O.P. and is currently a member of the Council of the British Acoustical Society.

During the years in Research Department, Mr Burd has worked in the field of architectural acoustics and has been closely associated with the techniques of studio design and testing. The work in this field is currently concentrated on modelling and its application as a studio design technique. A close association has been maintained with new buildings such as those in Birmingham.

Peter West has been delving into the history of engineering in the BBC since 1970. He started with the Corporation as a student apprentice in 1936. After the war he worked in the Planning and Installation and Engineering Information Departments, in External Services operations, and as assistant to the Chief Engineer. From 1960 to 1970 he was Head of Engineering, West Region.