BBC

ENGINEERING DIVISION

MONOGRAPH

NUMBER 51: **NOVEMBER 1963**

Radiophonics in the BBC

by

F. C. BROOKER, M.I.E.E.,
(Engineer-in-Charge, London (Sound))

BRITISH BROADCASTING CORPORATION

PRICE FIVE SHILLINGS

BBC ENGINEERING MONOGRAPH

No. 51

RADIOPHONICS IN THE BBC

by

F. C. Brooker, M.I.E.E.

(Engineer-in-Charge, London (Sound))

NOVEMBER 1963

BRITISH BROADCASTING CORPORATION

FOREWORD

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

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

Individual copies cost 5s. post free, while the annual subscription is £1 post free. Orders can be placed with newsagents and booksellers, or BBC PUBLICATIONS, 35 MARYLEBONE HIGH STREET, LONDON, W.1.

CONTENTS

Section	Title	Page
	SUMMARY	5
1.	INTRODUCTION	5
2.	HISTORY AND FUNCTION	5
	2.1 Early History	5
	2.2 Present Location and Area	5
	2.3 Function	5
3.	SOURCES OF SOUND AND THEIR MANIPULATION	6
	3.1 Natural Sounds	6
	3.2 Artificial Sounds	6
	3.3 Manipulation of the Signals	7
	3.4 The Resultant Signal	7
4.	WORKSHOP EQUIPMENT	8
	4.1 Workshop No. I	8
	4.2 Workshop No. II	9
	4.3 Copying and Editing Room	9
	4.4 Keying Unit	9
	4.5 Leevers–Rich Eight-track Recorder	9
	4.6 Twenty-channel Mixing Console	12
	4.7 Gunfire Effects Generator	15
5.	THE WORK OF THE UNIT	16
	5.1 The Producer and the Script	16
	5.2 Staffing the Radiophonic Workshop	17
	5.3 The Library	17
6.	CONCLUSIONS	17
7.	ACKNOWLEDGMENT	17
	APPENDIX	18

PREVIOUS ISSUES IN THIS SERIES

No.	Title	Date
1.	*The Suppressed Frame System of Telerecording*	JUNE 1955
2.	*Absolute Measurements in Magnetic Recording*	SEPTEMBER 1955
3.	*The Visibility of Noise in Television*	OCTOBER 1955
4.	*The Design of a Ribbon Type Pressure-gradient Microphone for Broadcast Transmission*	DECEMBER 1955
5.	*Reproducing Equipment for Fine-groove Records*	FEBRUARY 1956
6.	*A V.H.F./U.H.F. Field-strength Recording Receiver using Post-detector Selectivity*	APRIL 1956
7.	*The Design of a High Quality Commentator's Microphone Insensitive to Ambient Noise*	JUNE 1956
8.	*An Automatic Integrator for Determining the Mean Spherical Response of Loudspeakers and Microphones*	AUGUST 1956
9.	*The Application of Phase-coherent Detection and Correlation Methods to Room Acoustics*	NOVEMBER 1956
10.	*An Automatic System for Synchronizing Sound on Quarter-inch Magnetic Tape with Action on 35-mm Cinematograph Film*	JANUARY 1957
11.	*Engineering Training in the BBC*	MARCH 1957
12.	*An Improved 'Roving Eye'*	APRIL 1957
13.	*The BBC Riverside Television Studios: The Architectural Aspects*	JULY 1957
14.	*The BBC Riverside Television Studios: Some Aspects of Technical Planning and Equipment*	OCTOBER 1957
15.	*New Equipment and Methods for the Evaluation of the Performance of Lenses for Television*	DECEMBER 1957
16.	*Analysis and Measurement of Programme Levels*	MARCH 1958
17.	*The Design of a Linear Phase-shift Low-pass Filter*	APRIL 1958
18.	*The BBC Colour Television Tests: An Appraisal of Results*	MAY 1958
19.	*A U.H.F. Television Link for Outside Broadcasts*	JUNE 1958
20.	*The BBC's Mark II Mobile Studio and Control Room for the Sound Broadcasting Service*	AUGUST 1958
21.	*Two New BBC Transparencies for Testing Television Camera Channels*	NOVEMBER 1958
22.	*The Engineering Facilities of the BBC Monitoring Service*	DECEMBER 1958
23.	*The Crystal Palace Band I Television Transmitting Aerial*	FEBRUARY 1959
24.	*The Measurement of Random Noise in the presence of a Television Signal*	MARCH 1959
25.	*A Quality-checking Receiver for V.H.F. F.M. Sound Broadcasting*	JUNE 1959
26.	*Transistor Amplifiers for Sound Broadcasting*	AUGUST 1959
27.	*The Equipment of the BBC Television Film Studios at Ealing*	JANUARY 1960
28.	*Programme Switching, Control, and Monitoring in Sound Broadcasting*	FEBRUARY 1960
29.	*A Summary of the Present Position of Stereophonic Broadcasting*	APRIL 1960
30.	*Film Processing and After-processing Treatment of 16-mm Films*	MAY 1960
31.	*The Power Gain of Multi-tiered V.H.F. Transmitting Aerials*	JULY 1960
32.	*A New Survey of the BBC Experimental Colour Transmissions*	OCTOBER 1960
33.	*Sensitometric Control in Film Making*	DECEMBER 1960
34.	*A Mobile Laboratory for UHF and VHF Television Surveys*	FEBRUARY 1961
35.	*Tables of Horizontal Radiation Patterns of Dipoles Mounted on Cylinders*	FEBRUARY 1961
36.	*Some Aspects of Optical Lens Performance*	APRIL 1961
37.	*An Instrument for Measuring Television Signal-to-noise Ratio*	JUNE 1961
38.	*Operational Research on Microphone and Studio Techniques in Stereophony*	SEPTEMBER 1961
39.	*Twenty-five Years of BBC Television*	OCTOBER 1961
40.	*The Broadcasting of Music in Television*	FEBRUARY 1962
41.	*The Design of a Group of Plug-in Television Studio Amplifiers*	APRIL 1962
42.	*Apparatus for Television and Sound Relay Stations*	JULY 1962
43.	*Propagational Factors in Short-wave Broadcasting*	AUGUST 1962
44.	*A Band V Signal-frequency and a Correlation Detector for a VHF/UHF Field-strength Recording Receiver*	OCTOBER 1962
45.	*Vertical Resolution and Line Broadening*	DECEMBER 1962
46.	*The Application of Transistors to Sound Broadcasting*	FEBRUARY 1963
47.	*Vertical Aperture Correction using Continuously Variable Ultrasonic Delay Lines*	MAY 1963
48.	*The Development of BBC Internal Telecommunications*	MAY 1963
49.	*Apparatus for Measurement of Non-linear Distortion as a Continuous Function of Frequency*	JULY 1963
50.	*New Methods of Lens Testing and Measurement*	SEPTEMBER 1963

RADIOPHONICS IN THE BBC

SUMMARY

The term 'radiophonics' is taken (in the BBC at any rate) to mean the production of sounds from natural or artificial sources to convey the mood of a broadcast programme, but not the creation of musical compositions as such. This monograph describes the BBC's Radiophonic Workshop, the type of work which it undertakes, and the equipment used to create the desired sounds. Since the end product is almost invariably a tape recording, much of the equipment is necessarily concerned with the manipulation of tape recordings using fairly standard equipment. However, in order to carry out some of these manipulations, several ancillary pieces of equipment have been specially developed and these are described. The electronic gunfire effects generator is also described, although it is not strictly a part of the equipment of the Radiophonic Workshop; it was developed for direct, or 'spot', effects in studios some years before the workshop came into being.

1. Introduction

Wee haue also Sound-Houses, *wher wee practise and demonstrate all* Sounds, *and their* Generation. *Wee haue* Harmonies *which you haue not, of* Quarter-Sounds, *and lesser* Slides *of* Sounds. *Diuerse* Instruments *of* Musick *likewise to you vnknowne, some* sweeter *then any you haue; Together with* Bells *and* Rings *that are dainty and sweet. Wee represent* Small Sounds *as* Great *and* Deepe; *Likewise* Great Sounds, Extenuate *and* Sharpe; *Wee make diuerse* Tremblings *and* Warblings *of* Sounds, *which in their* Originall *are* Entire. *Wee represent and imitate all* Articulate Sounds *and* Letters, *and the* Voices *and* Notes of Beasts *and* Birds. *Wee haue certaine* Helps, *which sett to the* Eare *doe further the* Hearing *greatly. Wee haue also diuerse* Strange *and* Artificiall Eccho's, Reflecting *the* Voice *many times, and as it were* Tossing *it: And some that giue back the* Voice Lowder *then it came, some* Shriller, *and some* Deeper; *Yea some rendring the* Voice, Differing *in the* Letters *or* Articulate Sound, *from that they receyue. Wee haue also meanes to conuey* Sounds *in* Trunks *and* Pipes, *in strange* Lines, *and* Distances.

from: *The New Atlantis*, Francis Bacon, 1624

Such extraordinary prescience by this scientist-philosopher of three and a half centuries ago (he might well be called the first Science Fiction writer) is all the more remarkable because it was not entirely founded on precedent; most of the other wonders which he foresaw were merely elaborations or fairly obvious developments of (then) existing machines or known phenomena. It would be nice to think that his flight into fancy on the subject of sound was motivated by ideas of creating the incidental sounds to illustrate the works of his contemporary, Shakespeare, for it is precisely for this purpose, viz. the special effects for radio drama, that this modern version of Bacon's Sound-house was created.

2. History and Function

2.1 *Early History*

The Radiophonic Workshop was set up officially in 1958 although, for several years prior to this, special effects had been made, using normal equipment in studios equipped with recording apparatus. Also, small pieces of apparatus had been developed for producing (electronically) the types of distortion required to imitate telephone speech, for example.

The first workshop consisted merely of a room equipped with some rather nondescript recording machines, a few amplifiers and filters, a simple mixing desk, and a small studio. Because one of the oft-used manipulation techniques involves repeated dubbings from tape to tape, recorders of the highest standard are required. It soon became obvious that the Workshop could not do itself justice with its limited equipment and so it was reorganized in 1959 with improved equipment and additional staff.

2.2 *Present Location and Area*

When completed, the new Radiophonic Workshop and ancillary areas will occupy a total of 2,800 square feet. Fig. 1 shows a plan of the area and Figs. 2 and 3 (pages 10–11) give general views of the two main 'workshops'. The original, and quite inadequate, studio still forms part of the suite but this deficiency is offset by the fact that the Workshop is housed at the Maida Vale studio centre and access to any of the five large studios can be arranged fairly easily. Moreover, these studios between them house a conventional (pipe) organ, electronic organs, and a specially-designed Multicolourtone electronic organ.

2.3 *Function*

The main function of the Radiophonic Workshop is to produce sounds which convey to the listeners' imagination the *mood* or *emotional idea* behind the author's theme of his radio or television drama. Originally, as might be expected, radiophonic sounds were confined to sound broadcasting where there was less scope for creating an emotional atmosphere. It was not long, however, before television wished to borrow the resources of the Workshop to create sounds which were incidental to the picture but nevertheless helped to further the impression in much the same way as conventional incidental music serves to heighten a film or television programme. To this extent, the art of radiophonics may be likened in certain respects to abstract or impressionist art or music. Although the techniques employed sometimes follow the lines of that employed in the creation of the French '*musique concrète*', it is not the aim

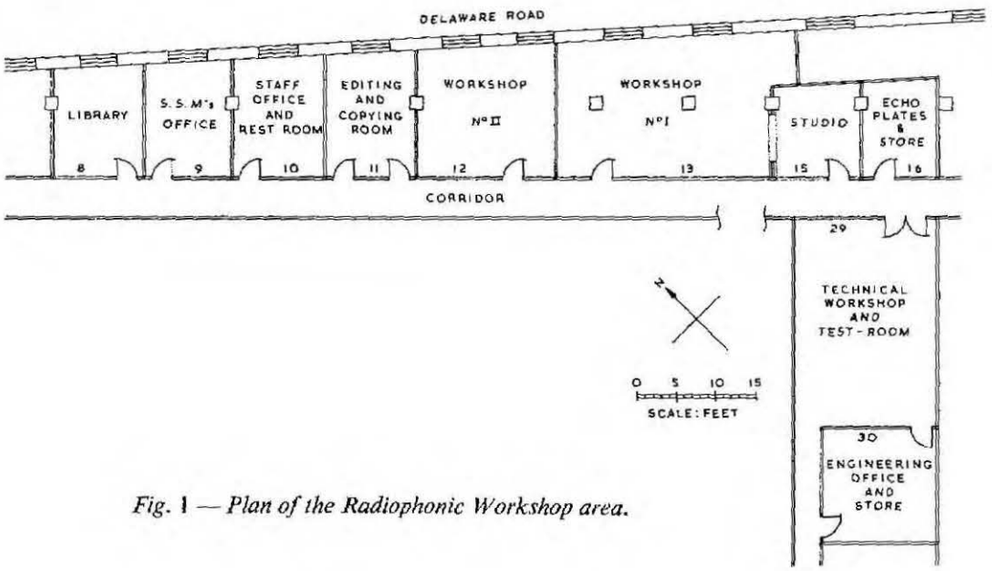

Fig. 1 — Plan of the Radiophonic Workshop area.

of the BBC's Radiophonic Workshop (at least, up to the present time) to create musical compositions *per se*. Musical tones and phrases (indeed, 'incidental music' for complete plays) are frequently called for and normal musical instruments are not excluded from the repertoire of sources of 'noise' which form the ingredients of radiophonic effects. Also, a conventional keyboard has been provided as a ready means of 'playing' the various sounds in rapid sequence.

3. Sources of Sound and their Manipulation

In general the source of the original sound falls into one of two classes: 'natural' or 'artificial'. There is no rule as to which should be used for a particular effect; it is largely a matter of experience and/or convenience. Often, a combination of both is the answer.

Because of the difficulty of describing, in words, the characteristics of various sounds, an attempt was made to illustrate the text by actual photographs of oscillograms showing the effects of manipulation on a particular waveform. The time scale involved made this impracticable and the author had therefore to resort to hand-drawn impressions of the cathode-ray tube display to illustrate these effects. It should be understood that the use of a cathode-ray oscilloscope was for the purpose of writing the monograph and it is not normally used as a tool of the Radiophonic Workshop.

3.1 *Natural Sounds*

Natural sounds could emanate from any of the conventional musical instruments (often used unconventionally!) or from the countless different sounds caused by striking, scraping, etc., any object with another.

They can be picked up by an ordinary microphone, using normal balance techniques and therefore incorporating the acoustics of the room, or by some special pick-up device attached directly to the vibrating source. Quite a different sound is produced, for example, from a piano string which is played in the ordinary way and picked up by a high-quality microphone placed some distance away from the piano than from the same string but with a crystal pick-up attached to the sounding board of the piano.

It is often found simplest to take a single 'note', or 'strike', of short duration and to record this for further manipulation (*q.v.*) rather than to attempt to create a complete musical sequence from scratch.

3.2 *Artificial Sounds*

Artificial sounds are those which are not initially produced acoustically; they are almost invariably generated by electronic means and are not, therefore, true 'sounds' until they have been converted to acoustic waves by a loudspeaker or similar transducer.

Electronically generated signals fall into two classes:

(i) *Oscillators* which can be individually tuned will provide 'notes' either of sinusoidal waveform or any desired waveform, e.g. square. As will be seen later, the output of a bank of such oscillators can be manipulated so as to combine their outputs, either simultaneously or 'keyed' in sequence as in an electronic organ.

(ii) '*White Noise*' *generators* containing the whole of the audio spectrum can be followed by filters which reduce or eliminate some of the frequencies to give it 'colour'. White noise itself sounds very much like the sound of escaping steam but, by eliminating certain bands of frequencies and manipulating it in such ways as controlling the rise and decay of a burst of

noise, it can be made to resemble almost anything from a pistol shot to a cat's purr.

3.3 *Manipulation of the Signals*

Having recorded the primary ingredients on separate bands of tape, one of the simplest types of manipulation is to play them via a multi-channel mixer, either together or in sequence. However, the original source of sound is rarely what is required and one or more processing techniques have first to be applied. Some of these are enumerated here:

(*a*) The single, short-duration, recorded tape is made into a small loop and played continuously to produce a repetitive sound which is dubbed on to a second tape.

(*b*) The original tape is played *backwards*. This completely changes the character of a note which, for example, may have had a sharp 'attack' (steep wave front) and a gradual decay but which now builds up slowly and ends with a plop.

(*c*) The original (or the reversed) tape is played at a different speed. Not only is the duration changed but often a completely different character emerges.

(*d*) The tape can be played at a *varying* speed, i.e. to give deliberate 'wow'.

(*e*) Parts of the tape (e.g. the build-up or the decay) can be suppressed or reduced, either by fading them out or physically cutting a section out of the tape.

(*f*) The signal can be subjected to a variety of frequency-discriminating circuits (filters) to alter its tonal values.

(*g*) Artificial echo, or reverberation, can be applied. In addition to the conventional methods of applying reverberation (echo rooms, reverberation plate, etc.) a method known as 'feed back' is sometimes employed. This consists of taking a feed of the replay amplifier output back, via a controllable attenuator, to the input of the record amplifier. The delay is that of the physical separation between the two heads but it can be further increased, and extra 'echoes' added, by allowing the tape to pass from the first machine and across the replay heads of any number of other machines before being taken up and spooled on to the final machine. Any or all of the outputs of the replay heads in the chain can be fed back in varying amounts to the first record head. Fig. 4 shows a diagrammatic sketch of an often-used arrangement.

A variety of 'flutter-echoes' may be obtained using this arrangement. The flutter frequency clearly depends upon the tape transit time from the *Rec.* to the *Rep.* heads and the rate of decrement depends upon the overall loop gain. Should this exceed unity, the system will build up to a distorted maximum limited by amplifier and/or tape saturation.

3.4 *The Resultant Signal*

Any, or all, of the above processes can be applied to the signal in any sequence. It is impossible to forecast, other than by experience, what the result will be. Fig. 5 shows an artist's impressions of the oscillograms taken of:

(*a*) The original sound, produced from a single note of a plucked piano string.

(*b*) The same note, with the second half removed by cutting.

(*c*) The tape of (*b*) played backwards.

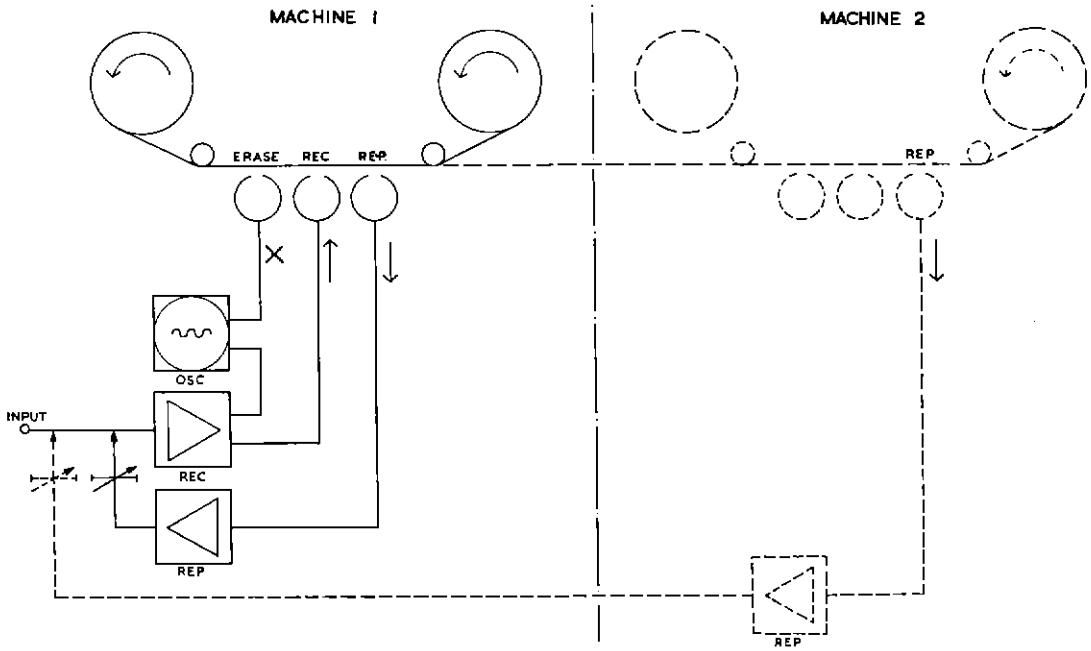

Fig. 4 — Block diagram of tape feed-back system.

(*d*) Time scale altered by halving the speed of tape.
(*e*) Echo added by simple feed-back process.

4. Workshop Equipment

The following list gives the equipment available at the time of writing. Much of it is standard, conventional equipment. Items of special interest constructed particularly for the Radiophonic Workshop, will be described in detail later.

4.1 *Workshop I*

(i) Seven sine/square wave signal generators.
(ii) Keying unit giving adjustable rise and decay characteristics (associated with (i)) (see 4.4).
(iii) Sine-wave signal generator.
(iv) White-noise generator.
(v) E.M.T. reverberation plate.
(vi) Artificial reverberation machine (magnetic drum type).
(vii) Four high/low-pass filters, each with nine cut-off frequencies.
(viii) Two variable-frequency response control units.
(ix) Octave filter.
(x) Two ring modulators.
(xi) Limiter.
(xii) Two Motosacoche tape recorders, with console (15 i.p.s.).
(xiii) Three Philips EL3503 tape recorders ($7\frac{1}{2}$ and 15 i.p.s.).
(xiv) Reflectograph tape recorder (variable speed, 3 to 8 i.p.s.).
(xv) Ferrograph tape recorder ($7\frac{1}{2}$ and 15 i.p.s.).
(xvi) Disk-playing equipment.
(xvii) Peak programme meters.

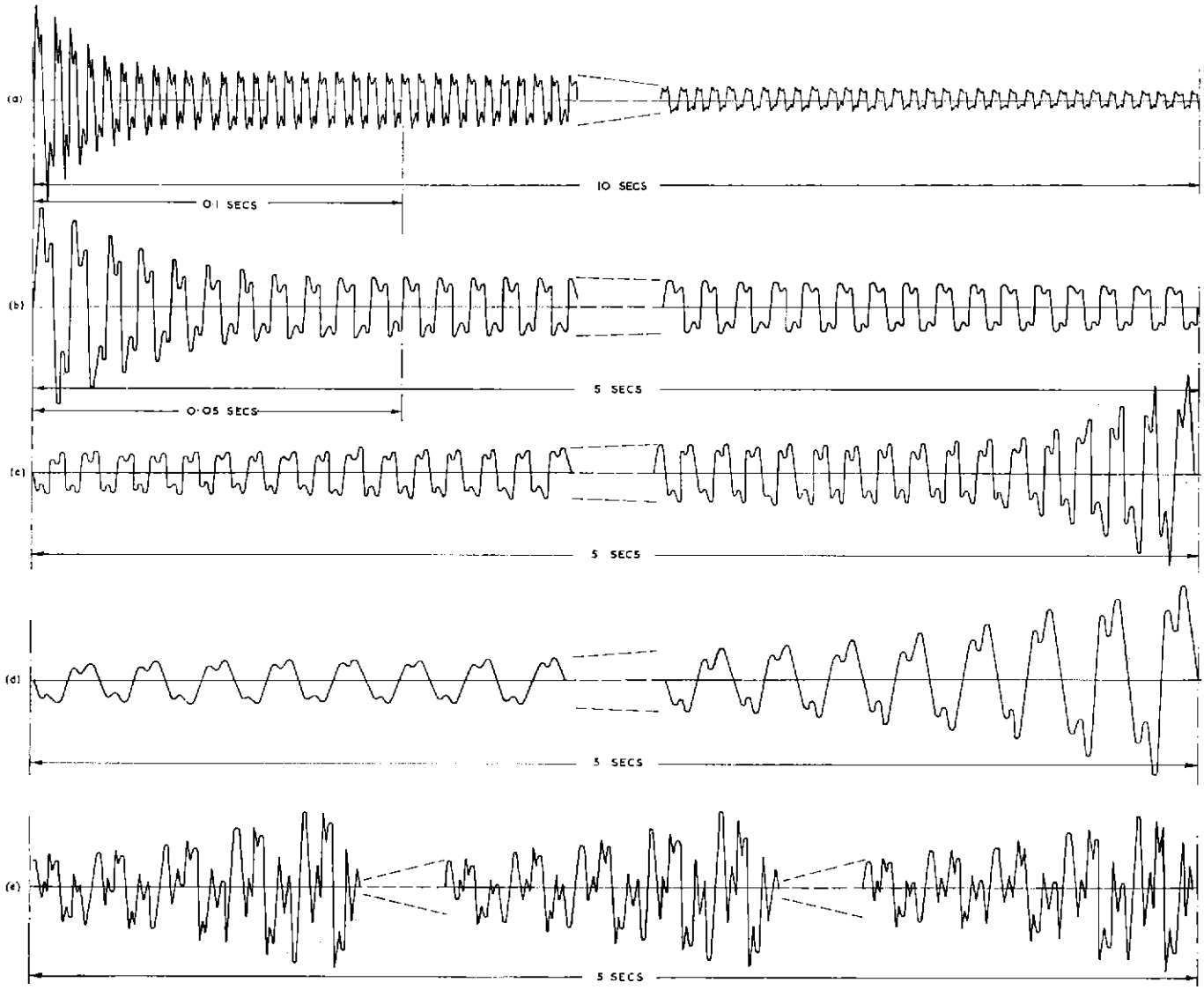

Fig. 5 — Drawings of C.R.T. displays (a), (b), (c), (d), and (e).

(xviii) Loudspeakers.
(xix) Twelve-channel mixer console, with acoustic foldback facilities.

4.2 *Workshop II*
(i) Twelve sine/square wave-signal generators.
(ii) Keying unit and (separate) adjustable decay unit (associated with (i)).
(iii) High-stability decade sine-wave signal generator.
(iv) Sine-wave generator with frequency modulation.
(v) Square wave shaper.
(vi) Zither and guitar with electromagnetic pick-ups.
(vii) E.M.T. reverberation plate, with remote control facilities.
(viii) Artificial reverberation machine (magnetic drum type).
(ix) Four high/low-pass filters, each with nine cut-off frequencies.
(x) Variable frequency response control unit.
(xi) Tierce filter.
(xii) Octave filter.
(xiii) E.M.I., BTR/2 tape recorder ($7\frac{1}{2}$ and 15 i.p.s.).
(xiv) Three Philips EL 3503 tape recorders ($7\frac{1}{2}$ and 15 i.p.s.).
(xv) Ferrograph tape recorder ($7\frac{1}{2}$ and 15 i.p.s.).
(xvi) Disk-playing equipment.
(xvii) Leevers–Rich eight-track tape recorder (0–40 i.p.s.) (see 4.5).
(xviii) Oscilloscope, Cossor double-beam.
(xix) Peak programme meters.
(xx) Loudspeakers.
(xxi) Twenty-channel mixer console (see 4.6).

4.3 *Copying and Editing Room*
(i) E.M.I., TR/90 tape recorder ($7\frac{1}{2}$ and 15 i.p.s.).
(ii) Ampex tape recorder ($7\frac{1}{2}$ and 15 i.p.s.).
(iii) R.G.D. tape recorder (15 and 30 i.p.s.).
(iv) Reflectograph tape recorder (3 to 8 i.p.s.).
(v) Ferrograph tape recorder ($7\frac{1}{2}$ and 15 i.p.s.).
(vi) Ferrograph twin-track tape recorder ($3\frac{3}{4}$ and $7\frac{1}{2}$ i.p.s.).
(vii) Four-channel mixer unit.

4.4 *Keying Unit*

For convenience in 'playing' sequences of electronically generated sounds, a short section (an octave) of a piano keyboard was adapted to make the necessary contacts to the outputs of the bank of signal generators. However, it was soon found that simple on-off switching was very limited in its application (in addition to suffering from key-clicks) and the Workshop engineers devised a modification to the keyboard which gave adjustable rise and decay characteristics.

The first attempt (now in Workshop II) consisted of a separate unit, bay-mounted, which had provision for twelve inputs for connection to the twelve keys of the piano-type keyboard. Each of the twelve separate circuits could then be adjusted to give various times of decay for the note when the key was released. There was no adjustment for the rise condition; the signal was simply switched into circuit.

The second model is illustrated in Fig. 6, which shows the unit connected to the bank of signal-generators associated with it. Fig. 7 shows the unit with its cover removed. Fig. 8 gives the circuit of one of the eight identical circuits which provide for variable characteristics of both the rise and decay of the signal.

The output of one of the sine/square wave signal generators is permanently connected to the input transformer T.1, the secondary of which feeds the grids of the 6060 double-triode. Bias to the extent of cut-off is applied by virtue of the voltage developed across the 470Ω plus the 4·7kΩ resistors and in this, the 'un-keyed', position, no signal is passed. Depression of the key causes both S.1 and S.2 to close. When these switches are closed, the bias is reduced to that developed across the 470Ω resistor only and this will allow the valve to conduct. The build-up of the bias is, however, controlled by the time-constant of R.1 and C.1 (10kΩ and 1μF respectively) which values have been chosen to give the minimum rise time (sharpest 'attack') consistent with the elimination of key-clicks. To produce a slower rise (more gradual attack), C.1 can be made greater by paralleling larger capacitors, C.1.2 (2μF) or C.1.3 (6μF), giving a range of three attack times, viz., *sharp* (0·01 sec), *medium* (0·03 sec), or *slow* (0·07 sec).

The decay is controlled by the time-constant of C.1 together with the resistance formed by R.2 (1·5 MΩ) plus the variable resistance, R.3. In the minimum position, this time is approximately 0·2 sec and this can be increased, in ten steps, to approximately 5 secs. In the '∞' position, the path to earth is broken and the charge on the condenser is retained, holding the bias in the conducting condition indefinitely so that the note continues even though the switch S.1 is broken by taking one's finger off the piano key.

4.5 *Leevers–Rich Eight-track Recorder*

This machine, illustrated in Fig. 9, was specially made for the Radiophonic Workshop by Messrs Leevers–Rich and utilizes 1-in.-wide tape, the effective recording width of each track being the same as that normally used for half-track recording on standard $\frac{1}{4}$-in. tape.

The eight record/replay heads are stacked vertically and a (separate) erase head is provided for the lowest (No. 8) track only. Eight record and eight replay amplifiers are provided. The tape transport and spooling systems are quite conventional from the mechanical point of view but the capstan motor has some unique features. It is a d.c. motor which obtains its power supply from a d.c. amplifier; a tachometer generator directly driven from the capstan motor provides a voltage which is fed back to the amplifier and provides the control. By this means, not only is a very satisfactory degree of speed constancy achieved but it is also possible, by varying the feedback voltage, to control the range of speeds from zero to 40 in. per second.

The principal application of this equipment is for the assembly of rhythmic radiophonic productions when perfect

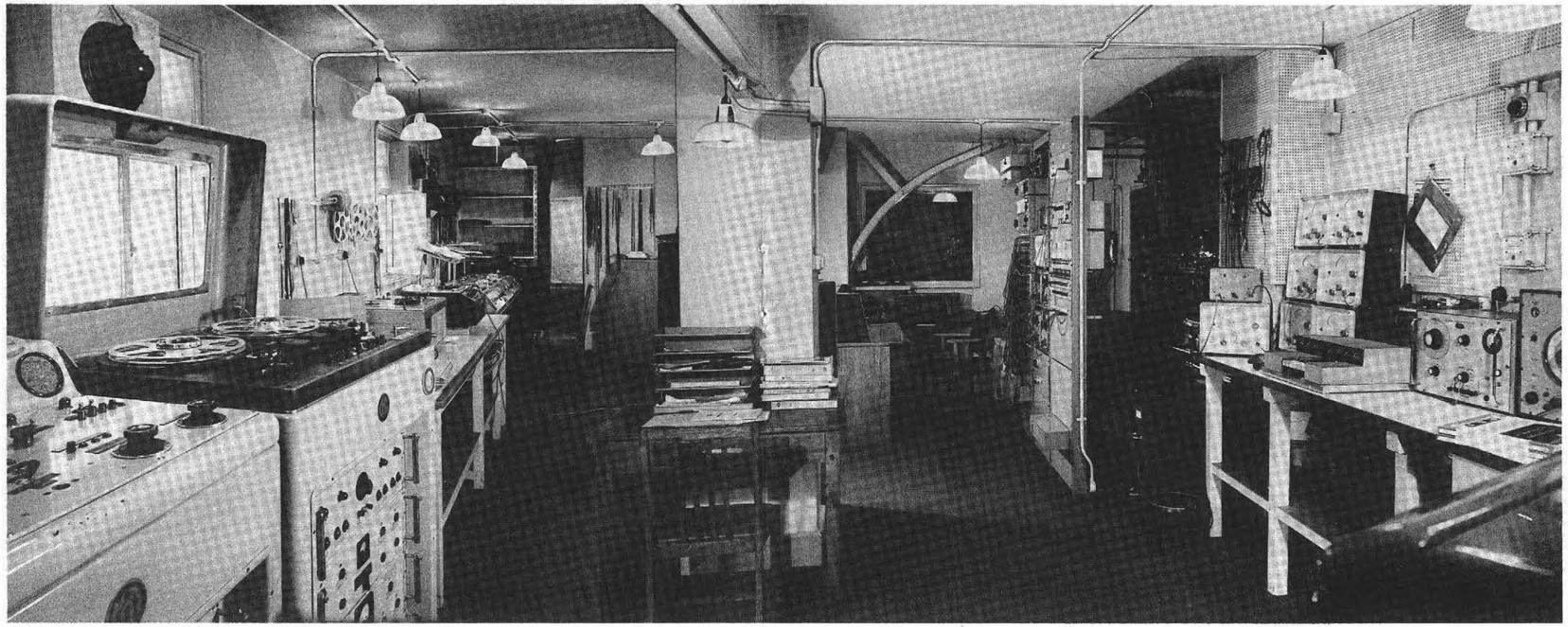

Fig. 2—General view of Workshop I.

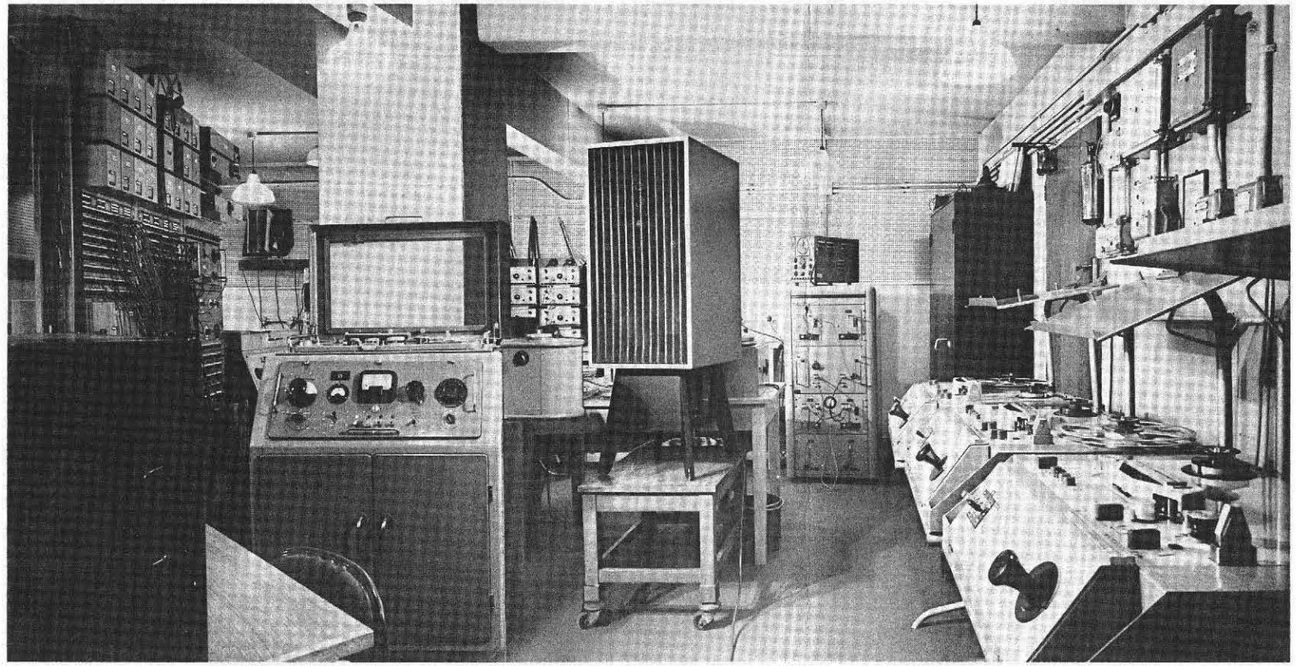

Fig. 3—General view of Workshop II.

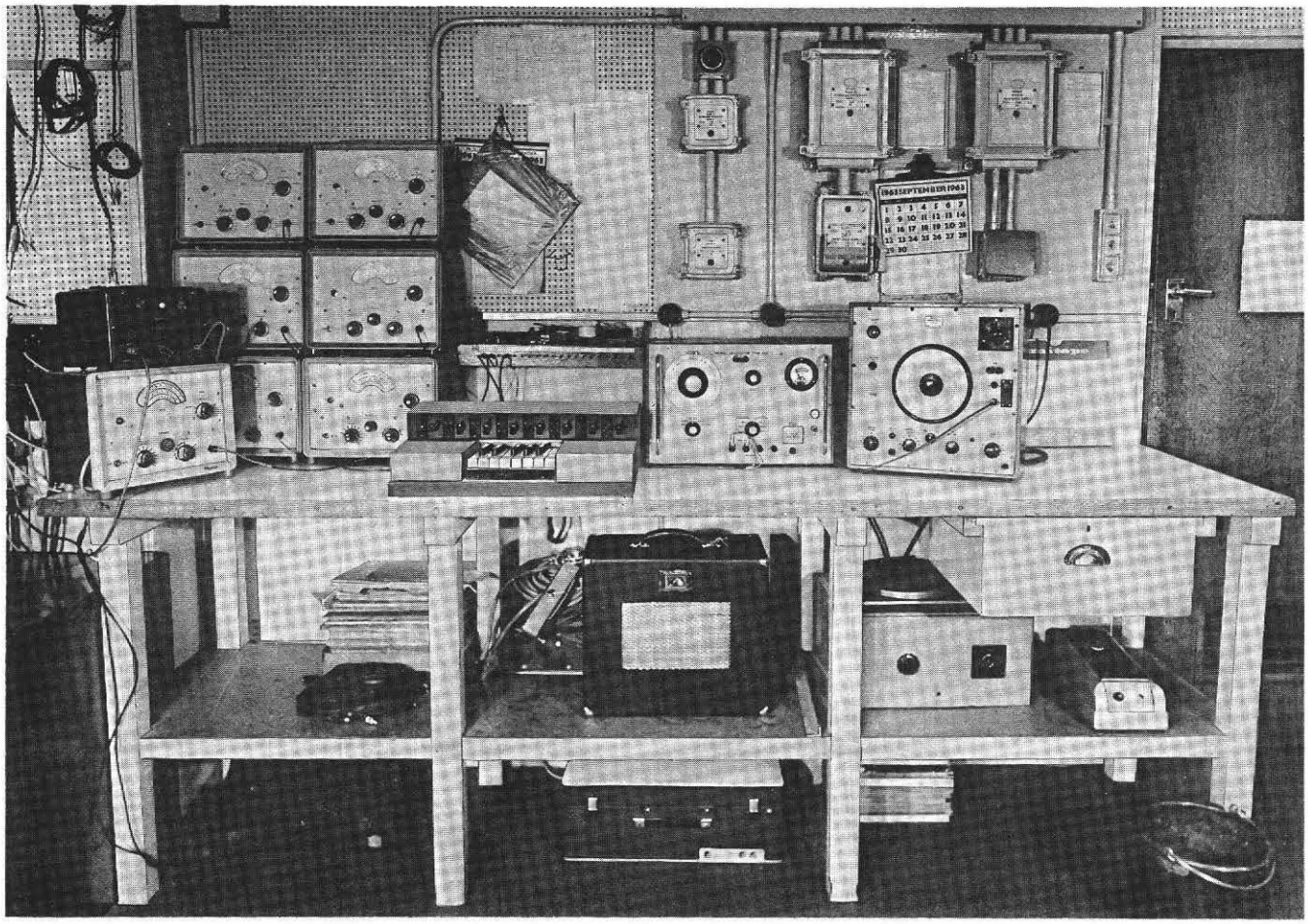

Fig. 6 — Photograph of keying unit with signal generators in background.

synchronization of the constituents is essential. The normal sequence of operations is as follows:

(*a*) Record guide material on track 1. This would normally be a rhythm derived from a loop of tape made on another machine.

(*b*) Whilst reproducing from track 1, the next component is recorded on track 8. When this recording is satisfactory, it is dubbed on to track 2. The unwanted material can now be erased from track 8, leaving it free for a repeat of the process for each of the remaining components, up to a possible total of eight.

(*c*) The completed tape is finally copied on to a separate single $\frac{1}{4}$-in. tape on a standard machine. The volume of each of the constituent tracks may be controlled during this process.

4.6 *Twenty-channel Mixing Console*

This console, illustrated in Fig. 10, was specially designed to meet the requirements of the Radiophonic Workshop and differs in many ways from standard BBC practice. Indeed, it would be true to say that it would not be 'approved' as normal studio equipment!

Quadrant faders have been used throughout, partly for space-saving considerations, but also because it is necessary to manipulate several channels simultaneously. The twenty channels were originally specified to be divided into two main sections, viz. (i) eight faders permanently associated with the eight outputs of the Leevers–Rich machine described in the previous section, and (ii) twelve faders, the inputs of which can be plugged to any sources in the Workshop. Whilst these arrangements are sensibly the same, modifications are constantly being made to the panel in the light of experience and new requirements; the remainder of this section therefore describes the state of the panel as it existed at the time of writing.

In addition to the twenty input channels, there are twelve other quadrant faders used for *group mixing*, *echo* controls, and *main* faders. The utilization of the total number of faders is, briefly, as follows:

(*a*) Eight channel faders with high-level (zero dB) inputs; these are normally associated with the replay outputs of the eight-track recorder.

(*b*) A single group fader (No. 1) to control the total output of the above eight faders.

(*c*) Eleven channel faders, each associated with an

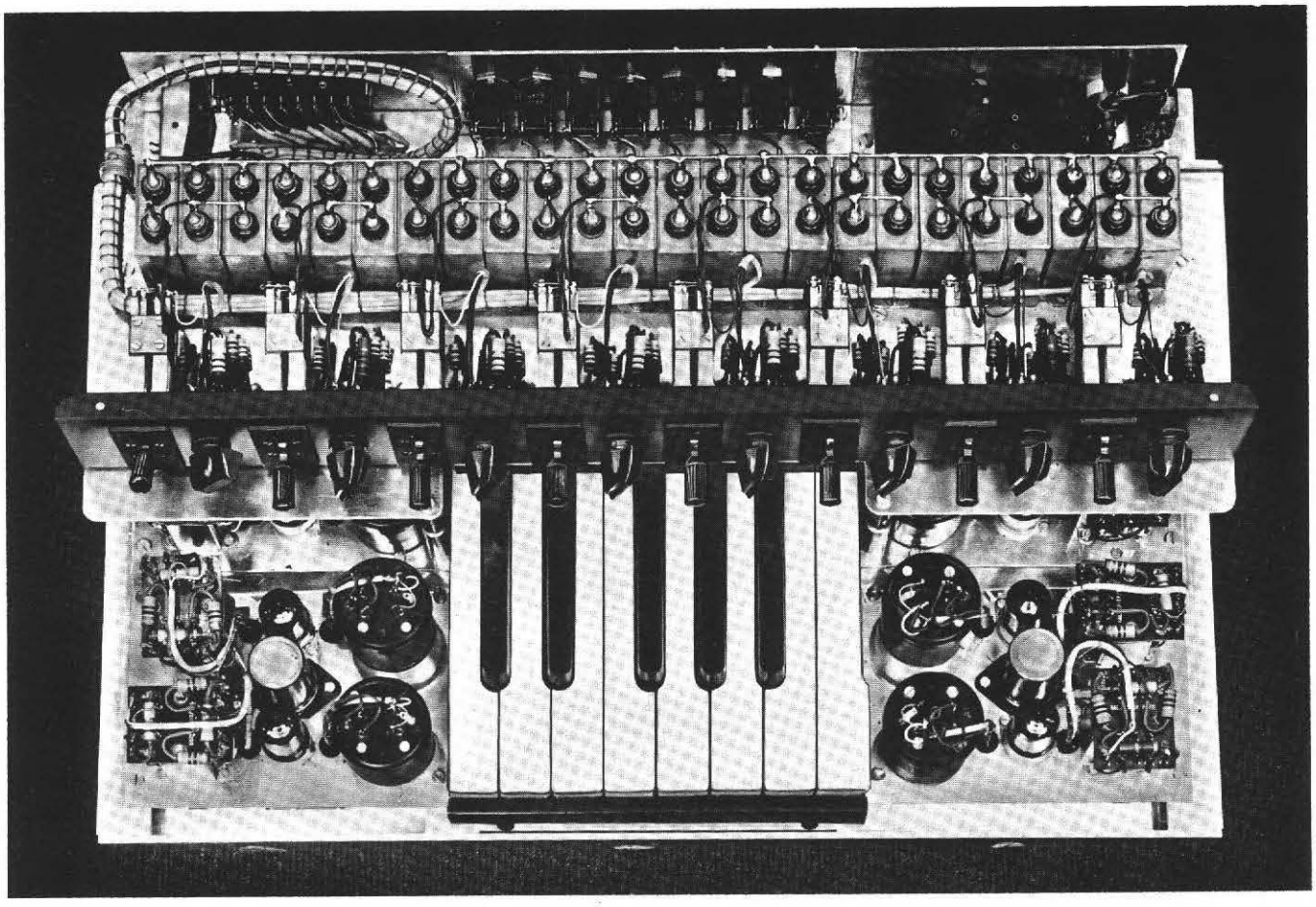

Fig. 7 — Photograph of keying unit, cover removed.

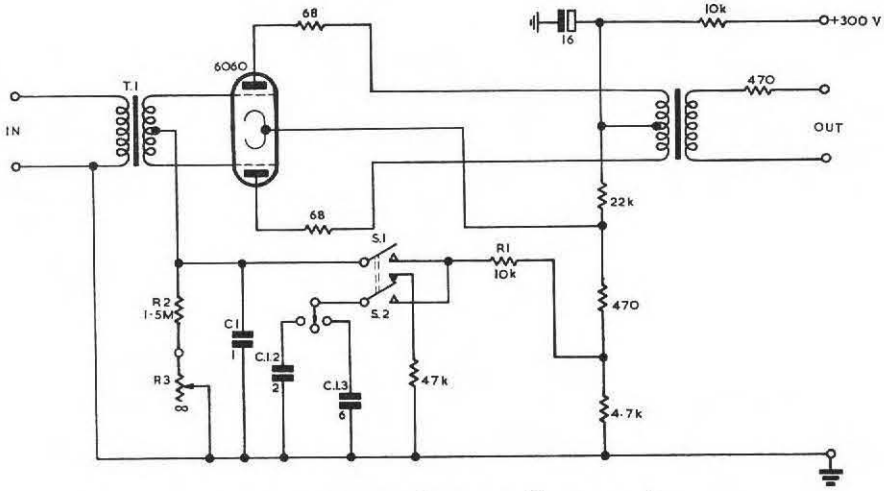

Fig. 8 — Circuit diagram of keying unit.

AMC/5 amplifier for use with low-level (−70 dB) sources. These amplifiers can be overplugged to cope with zero level sources, which level is normal for the outputs of such sources as the BTR/2, Philips, TR/90 or Ferrograph machines. Other outputs, such as microphones, gramophones, electric guitar, 'white noise' generator, and the two key-switch units (para. 4.4) are of low-level and require the AMC/5's in circuits.

(*d*) Two group faders (Nos. 2 and 3). The outputs of any of the low-level faders can be switched to either Group 2 or Group 3 fader. Also, the group fader No. 1 (controlling the eight high-level sources) can be switched to these groups.

(*e*) Independent channel. The outputs of any of the other faders (high or low levels) can be switched to this position and the outputs are then controlled only by the main control.

(*f*) Main control.

(*g*) Group 2. The output of this group is normally fed through an Albis Filter before being passed to the main control.

(*h*) Group 3. The output is normally fed through an effects unit filter before being passed to the main control.

(*i*) Two echo channels. Facilities exist for *three* types of echo, viz. (i) E.M.T. 140 Reverberation Plate, (ii) A.R.B. Artificial Reverberation Machine, and (iii)

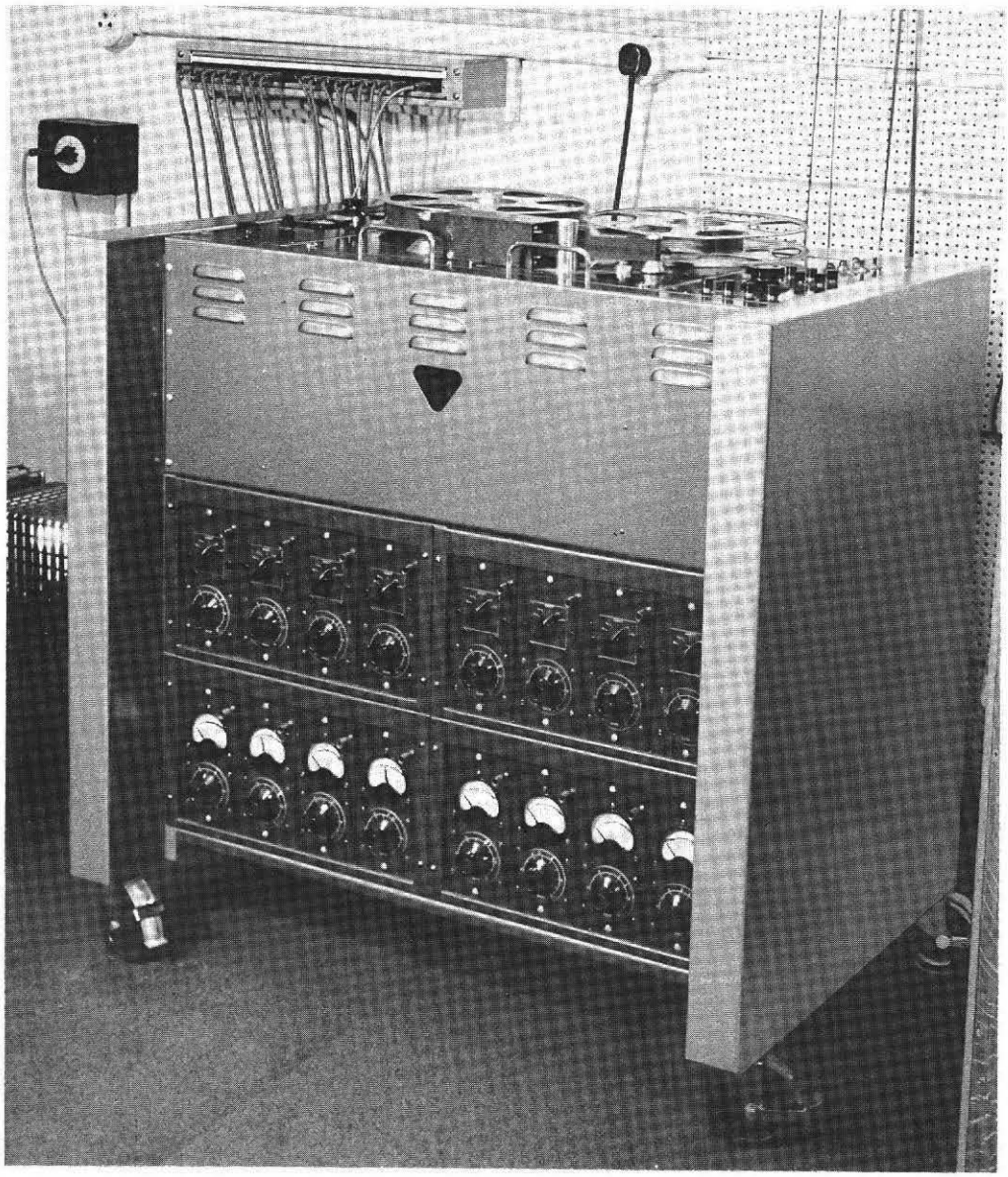

Fig. 9 — Leevers–Rich eight-track recorder.

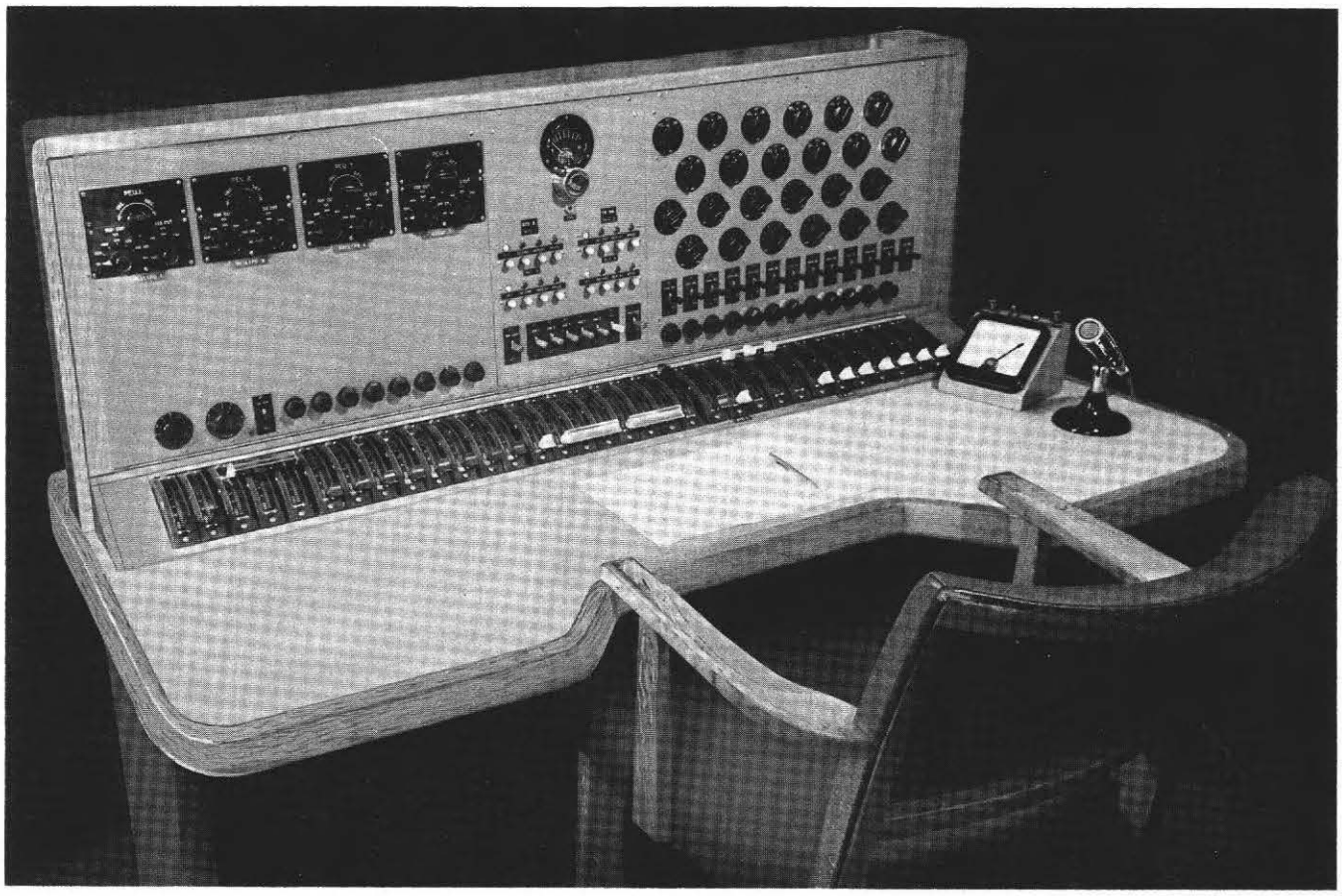

Fig. 10 — *Twenty-channel mixing console.*

Echo Room, but only *two* can be used simultaneously. The E.M.T. Plate is normally used on Echo 1 chain. Echo 2 chain is subdivided and the Echo Room is normally in the second chain of Echo 2.

The degree of echo or reverberation is controlled on each of the twenty channels by the normal ten-position echo mixture switch as used on standard BBC studio desks.

In addition to the channel faders and their functions outlined above, there are facilities for talk back, cue lights, and red light switching, loudspeaker 'dim' and volume controls, line-up tone and remote starting for four tape machines. Also, selected outputs from the panel can be fed back to a studio loudspeaker and thence picked up again by the studio microphone, thus giving acoustic foldback. This is known elsewhere in the BBC as 'Acoustic Effects', and is a normal studio function designed to make the addition of recorded effects from gramophone records match in acoustically with the other (live) material from the studio. It also enables the performers in the studio to take up their cues correctly; this might prove difficult if the 'effect' was not audible to them in the studio.

4.7 *Gunfire Effects Generator*

Prior to 1954, gunshot effects in drama were made either by the actual firing of a gun in front of a microphone or by slapping a ruler on to a table. The former, whilst being a pretty obvious method, was more difficult in practice than it seemed. The noise produced by a stage-pistol, firing blanks, does not sound at all convincing when picked up by normal means in a studio. Because of their comparatively loud peak energy, they had to be used a long way from the microphone and they sounded unreal. Then occasionally they 'misfired' (disastrous in a tense situation), they scared the performers, and they required a special licence and safe keeping to comply with Home Office regulations.

Because of all these difficulties the BBC Designs Department (the Radiophonic Workshop had not then been inaugurated) was asked to develop an electronic gunfire effects generator. Not only were they successful in doing this, but the device they produced was also found capable of being used for a whole range of sounds which cannot be made 'naturally'.

Essentially, the apparatus consists of a generator of 'white noise', a 'gate' which allows pulses of this noise to be triggered off and, finally, filter circuits to alter the char-

acteristic sound of the burst. This is shown in block schematic form in Fig. 11.

The push-button (mounted in a convenient handle on the end of a long lead) operates a relay which sends a positive impulse to the gating valve. After the impulse has been received, the bias on the gating valve is made to return exponentially to a negative value well below its cut-off. Thus a steep-fronted pulse of 'white noise', with an exponential decay, is released and this is passed through a low-pass filter. The L.P. filter was made variable, for the development work, and a cut-off value of 5 kc/s was found to give the best results for revolver shots (close), whilst distant gunfire is best represented by removing all except the lowest frequencies. Machine-gun effects are produced by causing an impulser relay to operate repeatedly for as long as the 'trigger' (push-button) is depressed and shortening the exponential decay time of each pulse so that they do not appear to run into each other and so give a blurred sound.

One of the effects which was often called for but which was quite impossible to achieve acoustically in a studio (they always had to use 'actuality recordings') was the *ricochet* effect so beloved of the makers of the Wild Western films. The electronic gunfire effects generator achieves it in the following manner. A separate pulsed oscillator is used, producing an output whose frequency falls off with time, and is rich in harmonics. This oscillator is also triggered by the impulser relay but it receives its pulse a short time after the triggering of the 'white-noise' pulse. Also, the gate is arranged to close before the oscillator frequency has fallen to too low a value. By judicious experimentation, a remarkably close approximation to the real sound of ricochet firing has been achieved.

The whole unit is built into a compact case (Fig. 12) and weighs only 12 lb. Experiments have shown that only slight modifications are required to produce other sounds such as squeaking doors and gates, bells, plucked strings (right down to double bass), steam-engine and motor-cycle noises, and a host of other sounds, either singly or repetitively.

5. The Work of the Unit

5.1 *The Producer and the Script*

Generally speaking, a producer will know, at the very outset of his production, whether he wishes to use special electronic sounds; indeed, the author or scriptwriter may have based his play on a certain theme with the foreknowledge that he would be calling for 'unheard of' sounds to illustrate it.

Typical of these are Science Fiction plays (e.g. the 'Quatermass' serials), fantasies such as 'Asylum Diary' or documentaries like 'Giants of Steam'. The producer (and perhaps the author) will first discuss the theme of the play and the content in which the sounds are to be produced with the staff of the Radiophonic Workshop. It may call for a complete 'musical score' although, as stated earlier, the function of the Workshop is not to produce *musique concrète* to stand on its own as a separate work. Its aim is neither to produce *natural* sound effects nor to produce conventional music; it is to produce an evocation of sounds to fit the needs of the particular programme, forming an integral part of it and heightening its intensity and meaning. In so doing, signature tunes and incidental music may well be called for, as will 'imitations' of everyday sounds, modified to give a particular impression or mood.

Having established the type of sounds called for, details such as duration and synchronization must be dealt with; the latter is particularly important if the sounds are to be used in conjunction with a film for television. The staff of the Workshop then begin their creation of the required sounds. Largely based on previous experience (it is possible that they will have used pieces of tape from previous productions to demonstrate to the producer the sort of thing they have in mind), they will gradually build up a series of sounds and these will be presented to the producer for his approval. Finally, when all the separate excerpts have been approved, they will be pieced together to form the 'score' either as a continuous tape or in bands separated by leaders.

It may be that the electronic sounds have to be added to a conventional musical score. This can either be done by pre-recording the Workshop material and 'playing' it, via a normal tape reproducer, into the orchestra (in other words, looking upon the tape machine as just another musical instrument 'cued in' by the conductor) or the separate tape recordings of the normal music and electronic effects can be mixed together, appropriately synchronized to get the correct beat.

In all of this work it must be remembered that this is a deliberate creative and interpretative process. It is not sufficient to select from a library a number of ready-made sounds and attempt to build them into a meaningful

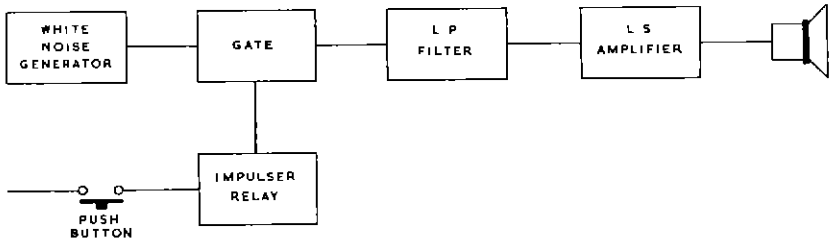

Fig. 11 — *Block diagram of electronic gunfire effects generator*

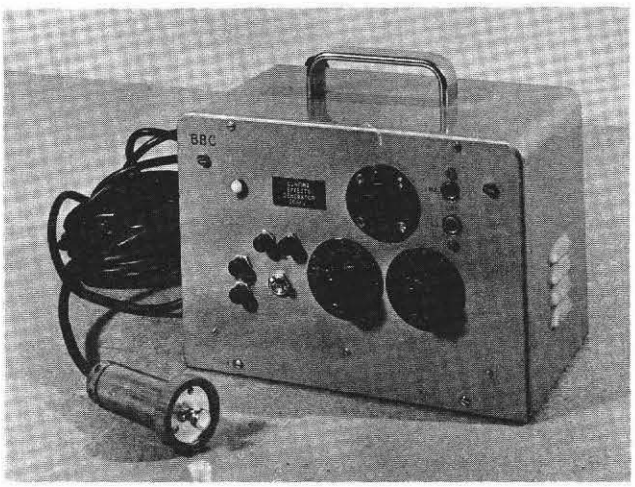

Fig. 12 — Photograph of electronic gunfire effects generator.

whole. It is very easy to produce unpleasant sounds; much more difficult to attain pleasant and beautiful ones.

5.2 *Staffing the Radiophonic Workshop*

The present staff of six is shared equally between Central Programme Operations Department which supplies a Senior Studio Manager, assisted by two Studio Managers, and Engineering Division, which supplies a Senior Engineer and his two assistants (an Engineer and a Technical Operator). Although the Studio Managers normally provide the musical knowledge that is essential to this work and the Engineers, of course, have the technical knowledge, there is a great deal of overlap and the staff have been chosen specifically for their wide qualifications. They must all be knowledgeable in the techniques of programme production, must have an interest in sound, music, and drama and the ability to understand and use electronic equipment in the most flexible way. Above all, they must be creative and ingenious.

5.3 *The Library*

A library of all the sounds and music which the Radiophonic Workshop has produced for transmission is kept, not with the object of using the material again, but purely for archive purposes. Whilst the same *techniques* may be used for different programmes, it is generally the best practice to create afresh for each new production rather than try to use 'second-hand' sounds. Nevertheless, a small library, coupled with a comprehensive card index system giving notes on how the particular effect was achieved, does save time on occasions, if only to give a lead on how to approach the problem. Also, of course, it will aid newcomers to the staff of the Workshop who have not the store of previous experience to draw upon. Generally speaking, staff find it more stimulating to create new sounds and, whilst not actually engaged on a production, spend the time available on experimenting and developing new techniques for use on future commitments. Complete productions of which radiophonic effects form only a small part are not normally retained in the library but certain productions have been selected as being of special interest.

A representative list of programmes which used radiophonic effects to the full is given in the Appendix, and an analysis of 500 productions over the past five years gives the following percentage distribution between the different BBC services and programmes:

Sound (Domestic, including Regions)	52 per cent
Television (All Regions)	35 per cent
Sound (External)	8 per cent
Exhibitions, Demonstrations, etc.	5 per cent

6. Conclusions

The use of radiophonic sound has become established—especially since the official start of the Radiophonic Workshop—as a valuable aid to the creation of the desired atmosphere in both sound and television broadcasts, and sometimes as the central feature of a programme. The same techniques are also being increasingly used for composing incidental music.

As the technicians and programme staff working in this new field gain more experience, they will probably acquire more of each others' skills, and develop an instinctive ability to predict which sources and which forms of manipulation will produce the appropriate sounds for a particular programme.

7. Acknowledgment

The author wishes to thank Mr D. G. Young, Senior Engineer, and Mr Desmond Briscoe, Senior Studio Manager, for their help in preparing this monograph.

APPENDIX

PROGRAMMES USING RADIOPHONIC SOUNDS

Title	*Type of production*	*Service*
The Disagreeable Oyster	*Fantasy for Radiophonics*	Third
Public Dreams and Private Nightmares	*Poem for Radiophonics*	Third
Under the Loofah Tree	*Fantasy for Radiophonics*	Third
Noah	*Biblical Drama*	Home
Quatermass and the Pit	*Science Fiction*	TV
The Goon Show	*Crazy Variety*	Home
Outside	*Experimental Drama No Scenery*	TV
The Warld's Wonders	*Scottish Medieval Drama*	Third
Embers	*Drama (Italia Prize Winner)*	Third
Radio Show	*Earls Court Exhibition*	E*
Music for Berlin Fair	*Soundtrack for British Pavilion*	E*
Presentation Links	*Interval Signal*	TV
Good Friday	*Religious Drama (J. Masefield)*	Home
West Highland Railway	*Documentary*	TV
The Insect Play	*Drama*	TV
David and Broccoli	*Drama*	Home
England's Harrowing	*Historical Drama (Thomas Hardy)*	Third
Phra the Phoenician	*Children's Hour, History Serial*	Home
Three Ring Circus	*Drama*	TV
Dune Roller	*Science Fiction Thriller*	Home
Things that Go Bump in the Night	*Dramatized Ghost Stories*	Home
The Navy Lark	*Variety*	Light
Collages	*Orchestral Concert with Tape Machine*	Third
Ideal Home Exhibition	*Earls Court Exhibition BBC Stand*	E*
The Administrator	*Fantasy-Drama*	Third
West Grinstead Park	*Documentary*	TV
Charing Cross Exhibition	*BBC Stand*	E*
Orpheus	*Drama, Cocteau*	Third
Music, Movement, and Mime	*Schools Broadcast*	Home
The Chairs	*Theatre of the Absurd*	TV
Sounds for Dartington Summer School	*External Music Course*	E*
Tourelle Skull (Suspense Series)	*Thriller*	TV
The Kingdom of the Green	*Children's Hour Historical Play*	Home
The Island	*Jazz Opera*	Stereo (S)
Giants of Steam	*Documentary on Railways*	TV
I Gotta Universe	*Fantasy for Radiophonics*	Home

* Special productions for exhibitions, demonstrations, etc.

BBC ENGINEERING TRAINING MANUALS

The following manuals by members of the Engineering Division of the BBC have been prepared primarily for the Corporation's operating and maintenance staff. They have been made available to a wider public so that the specialized knowledge and experience contained in them may be open to all interested in the engineering side of sound and television broadcasting.

Sound and Television Broadcasting: General Principles—K. R. Sturley, Ph.D., B.Sc., M.I.E.E. 45s. net, by post 46s. 4d. 378 pp.

This manual explains the basic principles of sound and television broadcast engineering and operations.

Studio Engineering for Sound Broadcasting—General Editor: J. W. Godfrey. 25s. net, by post 26s. 208 pp.
Explains the principles underlying current operational procedures at BBC studio centres. Covers the whole range of equipment used and the problems arising in the studio.

Television Engineering: Principles and Practice—S. W. Amos, B.Sc.(Hons.), A.M.I.E.E., and D. C. Birkinshaw, M.B.E., M.A., M.I.E.E.

Vol. I: Fundamentals, camera tubes, television optics, electron optics. 35s. net, by post 36s. 2d. 304 pp.

Vol. II: Video-frequency amplification. 35s. net, by post 36s. 2d. 270 pp.

Vol. III: Waveform generation. 30s. net, by post 31s. 2d. 224 pp.

Vol. IV: General circuit techniques. 35s. net, by post 36s. 2d. 277 pp.

These manuals are published by ILIFFE BOOKS LTD, DORSET HOUSE, STAMFORD STREET, LONDON, S.E.1. for the British Broadcasting Corporation, and are available from the publishers or from BBC PUBLICATIONS, 35 MARYLEBONE HIGH STREET, LONDON, W.1.

ENGINEERING TRAINING SUPPLEMENTS

		s.	*d.*
No. 1	Some Transmitter Problems	2	6
No. 3	Harmonic Distortion and Negative Feedback in Audio-frequency Amplifiers	7	0
No. 4	Some Fundamental Problems in Radio Engineering	4	0
No. 5	An Introduction to Slot Aerials	3	0
No. 6	Programme Meters	3	0
No. 7	Basic Principles of Television Lighting	5	6
No. 8	Microwave Valves	6	6
No. 9	Frequency Modulation	6	6
No. 10	Long-wave and Medium-wave Propagation	4	0
No. 11	Lighting for Television Outside Broadcasts	6	0
No. 12	Transistors	3	0

These Engineering Training Supplements are available from BBC PUBLICATIONS, 35 MARYLEBONE HIGH STREET, LONDON, W.1.

Published by the British Broadcasting Corporation, 35 Marylebone High Street, London, W.1. Printed in England on Basingwerk Parchment in Times New Roman by The Broadwater Press Ltd, Welwyn Garden City, Herts. *No. 5509*