Terminal Buildings at London Airport

(*Continued from page* 461, *April 1st*)

No. II—RADAR INSTALLATIONS

Certain air terminal buildings at London Airport are being commissioned this month; they include the control tower in which is based an unusually comprehensive system of surveillance and navigational aids. Here we give a brief description of some of the radar equipment, namely, the long range and medium range surveillance sets, the height-finding radar and the millimetric radar for indicating movement of aircraft on the ground.

Southern Air Traffic Control Centre

The new air traffic control centre for Southern England, which has been built at London Airport, will replace the air traffic control centre at Uxbridge, Middlesex, which was separated from the long-range radar unit at London Airport by 5 miles of telephone wires. The main advantage of the new centre is that for the first time the air traffic controllers will work directly alongside the radar unit.

The heart of the new centre consists of a control room 60ft by 50ft with a "service space" of the same size immediately below it. Only those items of radio and radar equipment required by the controlling staff are in the control room itself—the only radar equipments to be seen, for instance, are desk-mounted units. Associated

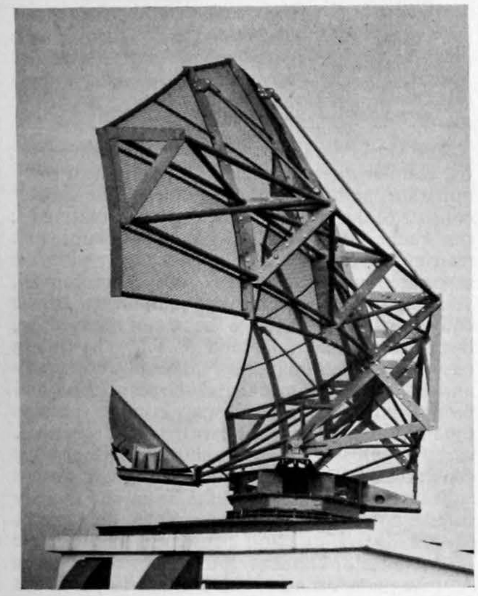

Fig. 1—The aerial of the "S232" set is a horn-fed parabolic reflector with a horizontal beam-width of 3½ deg. It rotates at 10 r.p.m. on the roof of a concrete building which houses the transmitter and receiver

equipment has been placed immediately below or in nearby equipment rooms, and is easily reached for maintenance without disturbing the operating staff. Special attention has been given in the control room to acoustics, air conditioning and lighting. The problem of combining ordinary room lighting with the prevention of glare on the radar screens has been solved by using three-colour lighting in the ceiling and special amber screens over the radar tubes. Groups of three fluorescent tubes of different colours—blue, green and red—give a mixed light that looks white. The special screens over the radar tubes allow only amber light to pass through; in this way the yellow radar blips can be seen clearly against a black background as long as the relatively bright room lighting is deficient in yellow.

Radar Installations

The radar installations at London Airport fall into five main categories, covering long-range (up to 120 miles) surveillance radar installations, a shorter-range installation, working up to 60 miles range, height finding, G.C.A. (ground control approach), landing equipment, and finally an aircraft surface movement indicator. Some of these installations are described below.

The controllers use long and short-range radars, which enable them to see aircraft on the screen immediately after take-off and to follow them out up to 100 miles; inbound aircraft are similarly treated. Radar used in this way enables separation between aircraft to be reduced with safety so that more traffic can be handled in confined air spaces. Radar can also be used to assist a pilot where navigation may be in error, to give warnings of other aircraft which may present a hazard and to route aircraft around unfavourable weather. In cases of doubt or where pilots have not reported their altitude or are not in communication with the centre, the controller is able to get an appropriate altitude from a radar height finder. At the Southern Air Traffic Control Centre there is at present one height finder, but two more will be installed.

Long-Range Surveillance Radar

An airfield control radar, type "S232," has been developed by Marconi's Wireless Telegraph Company, Ltd., for long-range surveillance and for close control of aircraft within the airport terminal area. An early development version of this equipment has been in operational use for some time, and from it has been evolved the new "S232" set, which is to be installed at London Airport in the near future.

Three points about the "S232" equipment are of particular interest. The first is that it operates in 50cm (500–610 Mc/s) band with the object of minimising the effects of rain and cloud. The second is the introduction of an improved

Brief Specification of Marconi "S232" Radar

Transmitter and receiver:	
Radio frequency	500–610 Mc/s crystal controlled (eleven spot frequencies are provided)
Peak power output	50–60kW
Pulse recurrence frequency	500–800 p.p.s. crystal controlled
Pulse length	2 or 4 microseconds (remotely controlled)
Receiver noise factor	8–10 db approximately
Receiver bandwidth (overall)	500 kc/s at 3 db down
Receiver intermediate frequency	45 Mc/s
Permanent echo suppression	At least 46 db, up to maximum range
Aerial System:	
Horizontal beam width ...	3½ deg. at 3 db down approximately
Vertical coverage...	20 deg. approximately
Polarisation	Horizontal
Tilt adjustment	−1 deg. to +10 deg. to the horizontal
Length of reflector	29ft
Height of reflector	10ft
Maximum speed of rotation	10 r.p.m. servo-controlled
P.P.I. displays:	
P.P.I. time-base ranges ...	0–20 to 0–120 nautical miles continuously variable
Range markers	5 and 10 nautical mile intervals
Additional P.P.I. facilities...	Off-centre, video map input, short time-constant; electronic azicator for height finder if required
Power requirements:	400V, 3 phase, 50 cycle, 12kVA (approx.)

M.T.I. (moving target indicator) system for differentiating between fixed and moving objects, cancelling the former from the viewing screen and leaving a clear field for the observation of aircraft. The "S232" is the only known airfield radar set that uses a crystal-controlled fundamental frequency to produce both the reference signal and the frequency stabilisation of the transmitted and received signals. This device is stated to give a permanent echo suppression better than 46 db, compared with a typical figure of 30 db for the so-called "coho-stalo" systems which use a free-running transmitter

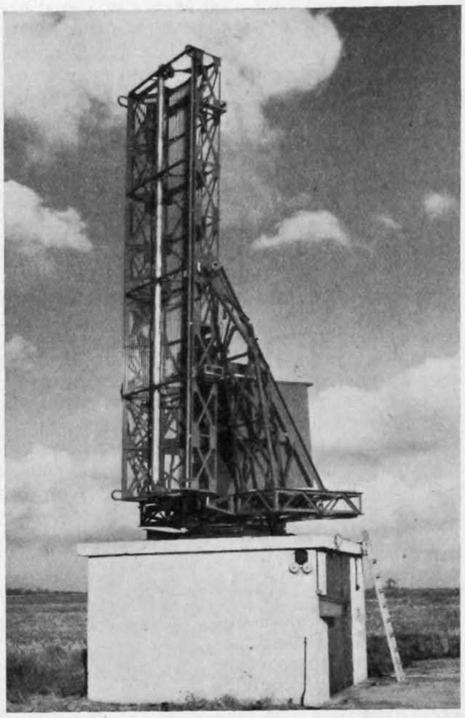

Fig. 2—The aerial system of the "S13" height-finder is a waveguide-fed paraboloid which oscillates ten times per minute about a horizontal axis and is rotated at 10 r.p.m. about a vertical axis

and various means of achieving coherence between the received echo signal and a reference signal. Because of the resulting reduction in permanent echoes this radar set can locate an aircraft at any range between about ¾ mile and 100 miles. Since up to eight P.P.I. (plan position indicator) displays can normally be used with one aerial head, the set can fulfil long and short-range functions simultaneously.

The third point is that the use of crystal control enables the set to be switched on and operated without requiring any tuning adjustment. Similarly, the M.T.I. system is stabilised and ready for immediate use.

The "S232" radar installation can be divided broadly into two parts: one is known as the aerial head and it consists of a small concrete building containing the transmitter, the receiver, and the drive for the rotating aerial and reflector assembly, which is mounted on the roof as indicated in Fig. 1; the other part includes the display equipment and auxiliaries and is installed in the operations building.

The aerial system, consisting of a parabolic reflector energised by an off-set horn, is designed to give a narrow horizontal beam width, together with a very small loss of power in side lobes. The vertical cover is approximately 20 deg. A thermostatically-controlled heating element is incorporated into the back of the horn for de-icing purposes. The reflector is an aluminium mesh supported on a light alloy framework, the whole structure being pivoted so that preset tilt may be applied in the vertical plane from −1 deg. to +10 deg. to the horizontal, the horn remaining at the reflector focal point at all times during tilt. By this tilting facility, the main beam may be raised in the vertical plane to alter the vertical cover. The horizontal beam width is approximately 3½ deg. at 3 db down (measured in one direction only) and depends on the radio frequency employed.

Control of the aerial turning mechanism is exercised from the radar office which houses the main display consoles, and provides the following facilities: continuous rotation of the aerial in either direction, at speeds from ½ to 10 r.p.m.; sweeping in a reciprocating cycle, over an arc of from 10 deg. to 60 deg. either side of any preselected mean bearing, at speeds of 1/17 to 2½ r.p.m.; and manual position-laying by means of coarse and fine controls at a speed of up to 10 r.p.m.

In the transmitter a frequency of 5·625 Mc/s is generated by a crystal-controlled reference oscillator and fed to the transmitter mixer unit.

Here it is mixed with a 60 Mc/s c.w. signal and the resultant 65·625 Mc/s signal is amplified and passed to the first doubler stage. There are two further doubler stages, then an intermediate amplifier and, finally, the power amplifier. The three doublers and the two power amplifiers are each pulse-modulated, the pulse duration being progressively narrower for each modulated stage to ensure a rapid build-up of r.f. amplitude at the start of each transmitted pulse, so that the time interval between the leading edges of successive pulses is very accurately maintained. The 60 Mc/s signal referred to above is derived from a separate unit embodied in the receiver, and consists of a crystal oscillator and a number of frequency multiplying stages. The crystal frequency is nominally 10 Mc/s, but up to eleven crystals may be selected to enable the transmitter to cover a frequency range of 500–610 Mc/s. The crystal frequency is multiplied six times to provide the 60 Mc/s signal to the transmitter, which, when mixed with the 5·625 Mc/s signal, is then multiplied up to the final radiated frequency. Assuming a fundamental frequency of 10 Mc/s from this oscillator unit, the transmitter output frequency is 525 Mc/s with an output power of 50–60kW at a pulse duration of 4 microseconds. The final transmitted pulse length can be set either to 2½ or 4 microseconds, either by local or remote control. A P.R.F. (pulse recurrence frequency) of 500–800 p.p.s. (crystal-controlled) is used.

In the receiver the echoes reflected from the target are picked up by the aerial system and pass, via a T/R switch unit, to the receiver, the first stage of which is a grounded grid coaxial triode r.f. amplifier. This stage is followed by a triode mixer, where the 525 Mc/s target signal is mixed with a local oscillator signal of 480 Mc/s (the latter also being derived from a frequency-multiplication of the 10 Mc/s crystal oscillator described above). The resultant 45 Mc/s signal is fed into an i.f. head amplifier, the output of which is taken by coaxial cable to the radar distribution unit in the operations building. Part of these i.f. signals are also fed via another amplifier in the receiver unit to a 6in "A" scan display monitor unit.

The radar display equipment in the operations building consists of two main parts. The first part is the radar distribution unit which receives the radar signals from the aerial head, converts them to video signals and sends them, with locally-generated calibration marks, to the P.P.I. display units which make up the other half of the display equipment. The P.P.I. display is produced on a flat-faced fluoride cathode-ray tube with moving-coil operation, and the facilities that it provides include off-centring, provision for multiple-head working, variable short-time constant and electronic azication for use with height-finding radar.

The radar distribution unit also contains the cancellation circuits for the moving-target indicator system. Briefly, their operation is as follows: the crystal-controlled 5·625 Mc/s reference oscillator provides the fundamental stabilising control for the whole equipment. One output at this frequency is fed to the transmitter, as previously described, while a second output is frequency-multiplied eight times (45 Mc/s) and fed to a "Homodyne" detector. The received (echo) signals, after conversion to an intermediate frequency of 45 Mc/s in the receiver, are amplified and also passed to the "Homodyne." This detector is therefore fed with 45 Mc/s from two sources, and its output will be proportional to the relative phases of the two signals. The phase of the locally produced oscillation will be fixed, while the received signal will be out-of-phase with it by an amount depending on the position of the target. It follows, therefore, that the received signal from a fixed object will always produce the same phase difference with every pulse, but a moving object will produce a phase difference which varies in amount with every pulse. To determine whether an object is moving or not it is only necessary to compare the "Homodyne" output produced by one pulse with that produced by the next pulse. A water delay line is used to achieve this discrimination, in the following way.

The output from the "Homodyne" detector (virtually video frequency) is used to modulate a 10 Mc/s crystal-controlled oscillator. The modulated oscillations are fed to a crystal which is mounted at the near end of a water-filled tube. They are converted by the crystal to mechanical oscillations at supersonic frequency (10 Mc/s) and as such travel along the tube, being reflected into another tube at the far end. This second tube lies parallel to the first, and the mechanical oscillations travel down it until they meet a crystal at the far end which reconstitutes them to electrical oscillations. The length of the tubes is so adjusted that the time taken for a pulse to travel from one crystal to the other is exactly equal to the time-interval between two pulses of the radar transmitter. The temperature of the water in the tubes is kept at 72 deg. Cent. by thermostat control. The output of the delay line is demodulated, and after inversion is mixed with demodulated signals which have not been delayed. Identical signals are thereby cancelled out; only those signals whose phases have changed between successive pulses appearing at the output of the mixer. These are rectified and fed through a video amplifier to three separate cathode followers, thence by coaxial cable to the P.P.I. consoles. Uncancelled signals are also fed to the consoles so that the operators may select either type of signal at will.

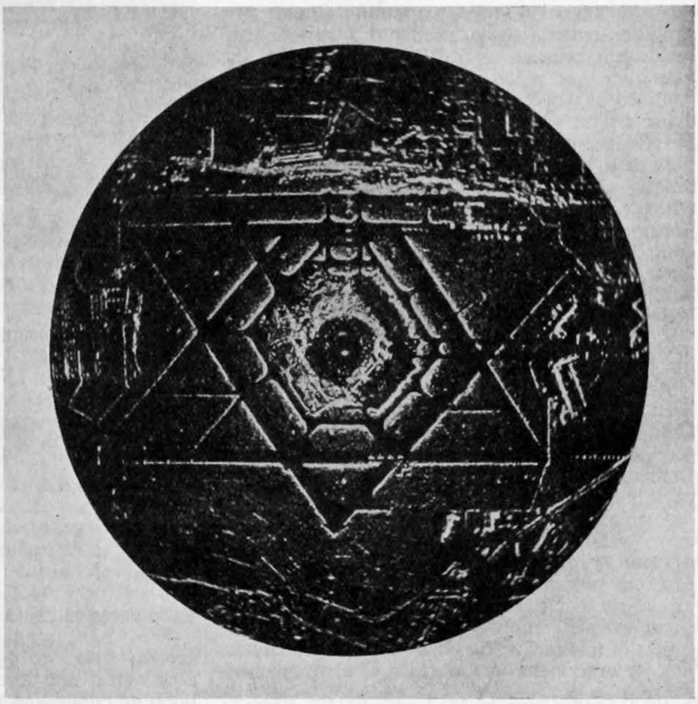

Fig. 3—Display showing movement of aircraft on upper and lower runways. Four positions of an aircraft produced on successive rotations of the scanner can be seen near the centre of the lower runway

SHORT-RANGE SURVEILLANCE RADAR

To give radar coverage of London Airport and its approaches up to a range of 60 nautical miles, a Cossor Airfield Control Radar, Mark VI, is being installed. Within this range the radar gives plan position indication on any number of display consoles up to three. On each of these displays any one of four range scales (10, 20, 40 or 60 nautical miles) can be selected independently and the centre of rotation can be offset from the centre of the tube by any amount up to the radius of the tube. Echo clutter from fixed objects is suppressed from the display by M.T.I. circuits, leaving only the moving targets over the full range of the set.

Because fixed reference marks are desirable on a surveillance radar (especially with M.T.I.), a system of video mapping is incorporated so that any desired diagram map can be introduced on the display to appear in true relationship, whatever range or offset is selected. To facilitate identification of responses, special circuits are included which accept output signals from the airfield automatic radio direction-finding system, and superimpose a radial trace on the display to indicate the particular radar response of the aircraft that is making the radio transmission. All the main electronic units are externally sealed and a built-in air circulation system continuously cools and dries the internal air. Special overheating auto-alarm devices are provided; in the event of fire the power supply is switched off and fire extinguishers are brought into action, while aural and visual warning are given. Metering and waveform monitoring facilities are incorporated as well as frequency and power output measuring instruments, to ensure correct setting up and operation with the least difficulty.

Technical particulars of the equipment are given in the accompanying tabular summary:

Main Particulars of Cossor Mark VI Airfield Control Radar

Frequency	2960–2980 Mc/s
Peak power	450kW
P.R.F.	850 per second
Pulse width	1 micro second approx.
Maximum range scale	60 nautical miles
Accuracy: ...	
Azimuth	± 1 deg.
Range	± 1 per cent or ± ¼ mile whichever greater
Discrimination:	
Azimuth	2 deg. separation
Range	¼ mile separation
Scanner rotation	10 or 15 r.p.m.

The Mark VI radar consists of four main parts: the scanner, the radar head, the equipment room apparatus and the display consoles. The scanner consists of the aerial and the drive for rotating it; the radar head contains the modulator and transmitter and part of the receiver with the associated power supplies and the control, ventilation and monitoring equipment. In the equipment room there are the rest of the receiver, both for normal radar and M.T.I., the timing circuits, video mapping, the power supply and control equipment, and the ventilation and monitoring gear. Each display console contains the P.P.I. cathode-ray tube with its e.h.t. supplies, together with a sweep amplifier, range marker generator and a special cathode-ray d.f. unit.

To avoid obstruction of the beam and thereby to give coverage at minimum range, the scanner is normally mounted on a tower so that the pole of the reflector is about 20ft above ground level. A waveguide connects the scanner to the radar head.

The reflector is an oblique section of a paraboloid, the pole being nearer to the bottom of the section. It is made of moulded plastics material, the reflecting surface being designed to withstand distort by heat or cold, water absorption or wind forces. The surface is metal sprayed to render it conducting, and does not discriminate against any particular plane of polarisation, so that circular polarising devices for anti-rain clutter may be fitted if required. The feed is via a waveguide rotating joint to an array of twelve horns, the distribution of power being such as to give a vertical coverage of the cosecant type. The mica windows of the horns are electrically heated for de-icing purposes by means of inconel elements, the necessary power being delivered via sliprings and a step-down transformer.

An all-welded structure of solid drawn steel tube carries the reflector and feed.

An 8 h.p. electric motor with star-delta starting drives the turntable through a gearbox, giving alternative speeds of rotation. High and low-speed "Telesyns" are incorporated which provide the necessary information for a scanner following unit in the equipment room to follow the rotation with great accuracy. A North-marker switch is provided, and a red obstruction lamp.

Additional aerial gear, such as secondary radar

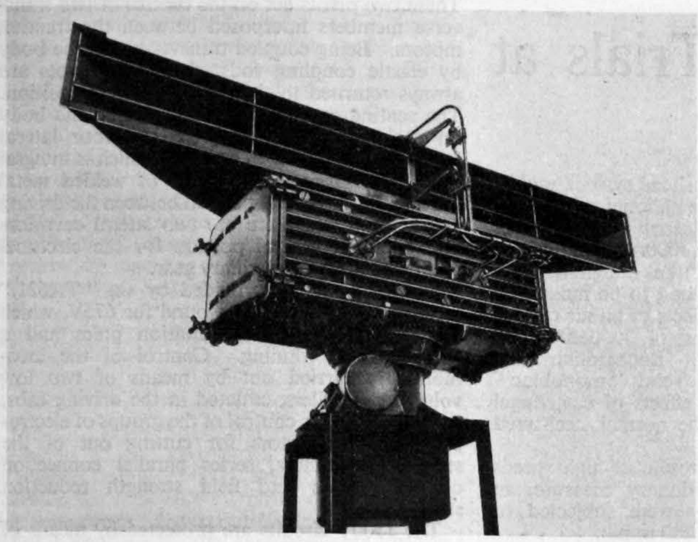

Fig. 4—Scanner and radar head of airfield surface movement indicator at London Airport. The input arrangements to the transmitting and receiving zones of the scanner can be seen

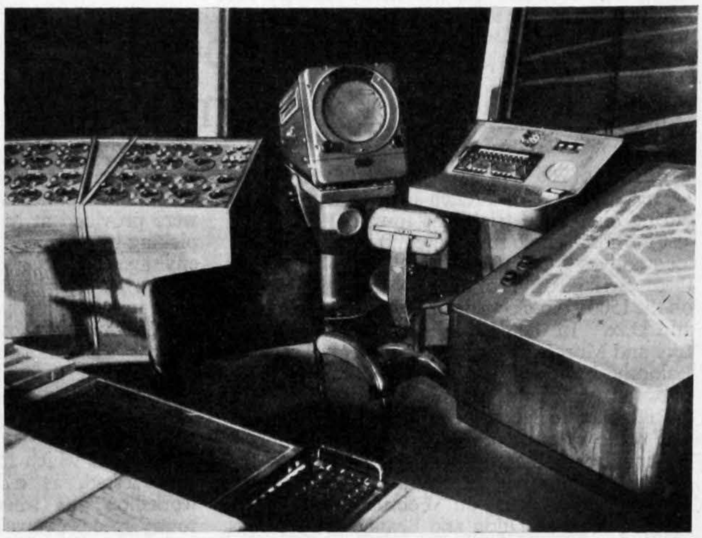

Fig. 5—Part of the air traffic control room at London Airport showing the surface movement radar display unit. The mimic diagram desk on the right is a separate equipment

or I.F.F. can be fitted and provision is made for the necessary extra sliprings and brushgear.

The radar head consists of apparatus contained in four steel cubicles. Three of these cubicles (r.f. modulator and power supply) are mounted on rollers running in floor rails. They can be released from the air trunking and electrical connections at the back and drawn forward to give access for maintenance. The fourth cubicle contains the control apparatus and it is fixed.

The equipment room contains five fixed cubicles from which the electronic equipment can be withdrawn whilst still functioning, on to a special servicing tray which fits into position on any cubicle.

Radar Heightfinder

Information about the height of aircraft flying within the range of London radar will be given to the controllers by a Marconi "S13" radar heightfinder used in conjunction with other radars. The "S13" set is a high-power, long-range set operating in the 10cm band.

The principle upon which this set operates is that the radio energy from the aerial system is transmitted in the form of a narrow beam 1 deg. wide vertically and approximately 5 deg. wide horizontally. This beam is tilted up and down vertically ten times per minute and thus scans an area of sky 5 deg. wide. When an aircraft has been located on the plan position (P.P.I.) display associated with one of the azimuth search radars, the aerial system of the heightfinder is rotated by remote control so that the aircraft is scanned by the radiated beam. When the beam crosses the aircraft the received echo causes a spot of light to appear on the cathode-ray tube display at the position appropriate to its altitude, and the necessary height information is then passed by the height-reading operator to the radar controller at the P.P.I.

Brief Specification of Marconi "S13" Heightfinder

Frequency	3000 Mc/s (nominal)
Pulse length	0·6 or 1·9 microseconds
Pulse recurrence frequency ...	500 p.p.s or 250 p.p.s
Peak power output	500kW (approx.)
Receiver noise factor	9–10·5 db
Receiver IF	45 Mc/s
Receiver band width	3·5 Mc/s or 1 Mc/s
Maximum range	150 nautical miles (270 km) (dependent upon target size)
Elevation	−1 deg. to + 25 deg.
Accuracy	±500ft (150m) at 50 nautical miles range (approx.)
Beam width :	
Vertical	1 deg.
Horizontal	4·5 deg. (for 6 db attenuation on either side)
Power consumption	12kW (approx.)
Power supplies...	230V, 50 c/s, three phase (delta connected), a.c. 230V, 50 c/s, single phase, a.c.

The heightfinder consists of an aerial head comprising an aerial system with its associated turning equipment together with a modulator, transmitter and receiver. The aerial system, which is mounted on the roof of a concrete building (Fig. 2) can be rotated horizontally at speeds up to 10 r.p.m., while the reflector and waveguide feed tilt ten times per minute in a vertical plane. Both transmitter and receiver are installed in the concrete building and the signals are fed by cables to the display equipment in the operations building.

The set operates on a wavelength of 10cm, at which ground reflections are not troublesome. The high-power transmitter is modulated by a 7kV pulse of short duration (0·6 or 1·9 microseconds) produced by a modulator unit with a pulse recurrence frequency of either 500 or 250 per second (nominal). Received signals are passed at video frequency to a display console, situated in the operations room, which employs an elevation-scan type of display to indicate aircraft heights.

The aerial system consists of a slotted waveguide positioned along the focal line of a vertical paraboloid reflector. Radiation takes place from the slots, which are so arranged that a narrow beam is produced in the plane of the waveguide. A "Perspex" cover protects the slotted section. Condensation is prevented by means of an air drier system. The reflector is made to oscillate in the vertical plane such that the radiated beam scans a vertical angle between −1 deg. and +25 deg. to the horizontal, ten times per minute. An automatic switch ensures that when the motor is switched off the reflector always comes to rest at its lowest position.

A direct presentation of the range and height of the aircraft is given in the form of an elevation-scan display on the cathode-ray tube. The target is indicated by a bright spot on the tube face, with a long after-glow. The trace pivots about a point at the bottom left-hand side of the tube face and tilts up and down in synchronism with the aerial system. The height of the target can be read off directly from the constant-height curves marked on the face of the tube.

Radar for Airfield Surface Movement Indication

As mentioned last week, ground movement control will be facilitated (particularly when visibility is bad) by the use of a millimetric radar set, which is known as an airfield surface movement indicator (A.S.M.I.). This equipment operates in the 8mm waveband (34,000 Mc/s) which enables it to produce a P.P.I. display image of the airport with a clarity and detail that would be beyond the scope of equipments using the conventional 10cm and 3cm wavebands. On this display (Fig. 3) all traffic, whether moving or stationary, on the runways or perimeter can be plotted. London Airport is believed to be the first airport in the world to be equipped with millimetric radar as a permanent installation for aircraft surface movement indication. The equipment is known as Q-band radar, and it was designed and made by Decca Radar, Ltd., 1-3, Brixton Road, London, S.W.9.

The scanner (Fig. 4), consists of a rotating double "cheese" system, with separate zones for transmitting and receiving; it is mounted on a short mast at the top of the 120ft control tower, whence it commands an uninterrupted radar view of all the runways and associated taxi tracks. There are two 12in diameter display units in the main air traffic control room; one display (Fig. 5) is for use by a ground movements control officer, who shares it with a lighting and route control officer; the other display is for use in conjunction with the standard navigational aids for monitoring take-offs and checking out-bound traffic. It is proposed to extend the A.S.M.I. facility at a later date by installing a third display in the approach control room, to work in conjunction with the G.C.A. and other landing aids.

Immediately below the scanner (Fig. 4) there is a cast housing, which contains the radar head, consisting of a magnetron, klystron and power pack and a modulator, mixer and pre-amplifier. The scanner and radar head are rotated as a single unit at 20/24 r.p.m. by a geared motor.

Main Particulars of Millimetric Radar for Airfield Surface Movement Indication

Frequency band	Within 8·69 mm–8·83mm
Aerial system :	
Reflectors	Double 6ft "cheese"
Horizontal beam	About 23 min. } At half power points
Vertical beam	About 14 deg. } At half power points
Side lobes	On inner lobes about 20 db down on main beam; outer side lobe better than 26 db
Pulse characteristics :	
Pulse generator	Triggered hard-valve modulator
Peak power	12kW–14kW
Duration	0·05 microsecond
Recurrence	About 4000 per second
Range :	
Discrimination	About 30ft
Accuracy :	
Range marker	Within 2 per cent
Range rings	Within 1 per cent
Minimum range	Down to few yards
Scales	0·5 mile, 1 mile, 3 and 10 miles
Bearing :	
Discrimination	About 25 min, measured at 1500 yards
Accuracy	±0·5 deg.

The receiver, which contains the v.f. and i.f. amplifiers, is arranged for wall mounting and, since it contains no operational controls, it can be fitted in an out-of-the-way position. Both linear and logarithmic characteristics are embodied in the i.f. amplifiers and they can be switched into circuit remotely from the operational display. The logarithmic receiver, the anti-clutter circuits and the fast-time-constant, offer means of suppressing interference from rain and snow.

The display (Fig. 5) is produced on a 12in diameter fluoride cathode-ray tube, which has a long after-glow characteristic. A cowl is fitted to obtain optimum presentation of the display under high intensity room lighting conditions. In addition to the normal display controls, there are facilities for line/logarithmic i.f. switching, fast-time-constant, and anti-clutter control. A directly-calibrated range stroke marker is fitted. The bearing scale is illuminated and calibrated in degrees and the cursor is rotated manually.

Power for the radar set (about 2kW) is obtained from a motor alternator generating at 80V, 1000 c/s, with a voltage control panel.

(To be continued)