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# The Aerial Papers in this Issue

is a curious fact that the Radio Antenna tends to be somewhat of a nderella in the telecommunication family; certainly young engineers ed to be much persuaded that the study of aerials is a worth-while tivity and every whit as fascinating as transistors or the electronic azes of computer work.

Every radio installation begins or ends with an antenna and no other ement in the signal chain contributes more significantly to the perform-ce of the system as a whole. It is for this reason that aerial investigations all types figure largely in the programme of the Marconi Research boratory.

Radar aerials have received particular attention because of the difficulty meeting the stringent operational requirements demanded by the Civil r Traffic Control authorities as well as by the military. This work has l to aerials of large aperture, high gain and patterned directivity com-ned with low side lobes. The testing of such aerials has posed some fficult problems of measuring technique, instrumentation, mechanical ndling and harsh economics. Some of these points are touched upon in e three papers contained in this issue; in addition, the papers seek to ow that the large antenna is a vital tool in the radio survey of the iverse around us—it is, in fact, the radio telescope whose influence on tronomy during the last decade has been so dominant.

E. EASTWOOD

# AERIAL INVESTIGATIONS USING NATURAL NOISE SOURCES *

By E. EASTWOOD, Ph.D, M.Sc, M.I.E.E.

*Radio frequency noise from the sun was first observed as an interfering sign on certain longwave R A F and Army radars in* 1942. *Since that time a numb of observations on the noise arising from the active sun have been made o radars operating at various frequencies, but it is only with the development receivers of increased sensitivity, fed by aerial systems of high gain, th the quiet sun is now observed as a matter of routine.*

*The following article describes experiments which utilize the quiet sun as noise source at varying angles of elevation, in order to establish the radiati diagrams of the high performance radars required to provide the operation environment demanded by modern aircraft.*

*The sun is a variable noise source and during its brief periods of enhanc ment spectacular radio and radar effects may sometimes result. A descripti is given of observations at* 215 *Mc/sec made on the active sun of October* 27 1955 *when evidence was obtained which suggests that a moon reflected sign was also obtained.*

*Records are presented to illustrate the enhancement of the sun at sunri on July* 14*th* 1959. *This event was followed by the reception of signals July* 15*th* 1959, *which may be explained in terms of auroral activity conseque upon the arrival at the earth of charged particles emitted by the active su*

## Introduction

The discovery by Jansky(1) in 1931 that radio noise was reaching the ear from the general direction of the Milky Way did not lead, as might supposed, to the immediate detection of radio waves emanating from t sun. It was to be expected that such electromagnetic radiation would emitted from the sun in accordance with black body theory, but it w not until 1944 that Reber(2) succeeded in demonstrating the presence solar radiation at a wavelength of 1·87 m followed in 1945 by Southwortl account of his experiments at 10 cm(3). The intensity of the solar rad flux at these wavelengths proved to be in rough agreement with the le expected from a black body at 6,000°K.

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* The first part of this paper is based upon a lecture given in Copenhagen in October, 19 to the Avionics Panel of the Advisory Group on Aeronautical Research and Developme to N.A.T.O.

Direct proof of the emission of radio noise from the active sun had
en made as early as 1942, however, when a number of Army and Air
rce Metric Radar Stations reported an increased noise level coming from
bearing corresponding to and moving with the sun. The phenomenon
s analysed by J. S. Hey(4) of the Army Operational Research Group
d correlation of the radio effect with the movement of a large sunspot
ross the solar disc was convincingly demonstrated.

A detailed study of the radio effects accompanying the marked sunspot
tivity of February 1946 was made by Appleton and Hey(4) when useful
servations were again made at various service radar stations, in addition
the detailed measurements made by Hey and his group on radar
rived equipment. These measurements covered the wavelength band
cm-15 m and established the radio phenomena accompanying the
currence of a major sunspot disturbance.

As noted in the paper by Appleton and Hey(4) the RAF contribution
this series of observations was made by the author, assisted by Mr. F.
psey and Mr. H. Crossland, and employed the 60-Group radar stations
erating in the 10 cm 1·5 m and 10-15 m wavebands. For the 10 cm
servations the Type 14 plan position sets and Type 13 nodding height
ders were used, but no increase in noise level was observed on these
uipments when their beams traversed the sun. The CH sets in the
-15 m band showed an increased noise level on the A-Type displays
hich were employed, and it was possible to DF this signal by the usual
niometer technique to show that the bearing corresponded with the
aring on the sun. The 1·5 m GCI equipments showed enhanced noise
the A-scope trace when the aerial beam swept through the azimuth of
e sun, and the increase in the noise could be roughly measured from the
be, or by monitoring the second detector current when the aerial was
pped on the sun's bearing.

The methods of elevation measurements employed by the CH and
I sets proved difficult to apply on the solar noise signal, but were
fficient to show that the signal source moved in elevation roughly in
cordance with the sun's motion.

It is interesting to remember that, during these experiments, no trace
the sun's noise could be seen upon the PPI of the GCI set, and even the
-scope observations were possible only during the active period of the
n; efforts to observe the quiet sun upon the CH and GCI equipments
re unsuccessful.

## arameters of the Wartime GCI Radar

e wartime GCI set of the RAF operated on a frequency of 209 Mc/s
d had an effective noise figure of 19 dB due to the degradation introduced
the capacity switching network and the duplexer. The low cover aerial

consisted of four bays; each bay was made up of four full-wave, horizont dipoles, i.e. thirty-two half-wave dipoles placed $\frac{\lambda}{8}$ in front of a wire mes reflecting screen. Thus the free space power gain of the array, afte allowance for feeder losses, was 19 dB. The horizontal beam width was i the order of 12°. PPI observations were made upon a double layer scree of rather poor afterglow characteristics so that little signal integratio was possible. Signal amplitude measurement was made from an A-sca tube having a phosphor of similar afterglow properties.

The set noise corresponding to the noise figure of 19 dB is $3{\cdot}18 \times 10^{-1}$ watts/Mc/s while the power available at the receiver from the solar nois flux at the earth's surface, corresponding to black body radiation from th sun at a temperature of 6,000°K and for an aerial gain of 19 dB is $7{\cdot}06$ × $10^{-17}$ watts/Mc/s. If we allow for the effective increase of gain produce by the earth's reflection, the noise power at the peak of the lobe is fou times this figure, i.e., $2{\cdot}8 \times 10^{-16}$ watts/Mc/s. Thus the solar noise wa down on the set noise by a factor of 1,000, and was not visible excep during periods of extreme enhancement of the solar activity. If blac body theory were obeyed, the effective temperature would have to ris well above $10^6$ °K for a noise signal to be visible.

## Solar Noise Observations at 215 Mc/s with PPI Recording

During some recent experiments upon a modified 1·5 m type radar, solar noise signal was observed as a matter of routine upon the PPI durin those hours of the day when the sun was rising or setting through th lower ground interference lobes of the aerial, whilst a period of increase solar activity around October 27th 1955 gave some spectacular solar nois signals upon the PPI. It is these observations which have prompted th present appreciation of the sun as a noise source in radar antenna studie

For comparison with the parameters of the 1·5 m radar given above the present experimental equipment operated on a frequency of 215 Mc/ and had a noise figure of 8 dB so that the level of background noise in th receiver was $2{\cdot}5 \times 10^{-14}$ watts/Mc/s. The aerial was an array of horizont half-wave dipoles distant $\frac{\lambda}{8}$ from the screen as before, but increased i number from thirty-two to ninety-six. The gain now appears as 24 d after due allowance for feeder losses. The black body flux presented to th aerial for a surface temperature of 6,000°K and at a frequency of 215 Mc yields a solar noise power available at the receiver of $2{\cdot}12 \times 10^{-1}$ watts/Mc/s (free space) which corresponds to $8{\cdot}4 \times 10^{-16}$ watts/Mc/s a the first interference maximum. This signal is 14 dB down on the set noise evertheless, a clearly discernible noise signal is painted on the PPI t the bearing corresponding to the sun, and moves in azimuth in accord- nce with the sun's diurnal motion. The character of the signal and the hange of bearing with time is clearly shown in Fig. 1. The ratio $\frac{\text{olar noise amplitude}}{\text{set noise amplitude}}$ for the record at 15·20 hours GMT was measured on n A-scope as $4/_1$, which is 26 dB above the flux expected for a black body t 6,000°K.

These radar observations confirm in a simple and vivid way the con- lusions of the radio astronomers($^5$) that the radio emission from the sun emands an effective temperature much higher than the 6,000°K of the hotosphere, or that a radiative process other than provided by black ody theory is involved.

Improvements in receiver noise figure and aerial gain have both contri- uted to the success of this simple technique of PPI display of solar noise gnals, but if comparison is made of the power ratio $\frac{\text{solar noise}}{\text{set noise}}$ for the two ts, i.e. an increase of 16 dB, it will be seen that a further important ntribution to solar noise detection comes from the integrating property f the modern phosphor screen. The PPI record was photographed from cathode ray tube which employs a magnesium fluoride phosphor, having n afterglow characteristic corresponding to a decay time of 30 secs. to 0% intensity after a single excitation. The CRT spot diameter is in the rder of half a millimetre, so that for an aerial turning speed of 4 r.p.m. nd a time base repetition frequency of 250 pps, integration of the signal ver four or five traces was obtained; in the radar case for these same perating conditions it is usual for ten paints on an aircraft track to be en on the tube at any instant.

## olar Diagram Measurements at 215 Mc/s ith the Sun as a Noise Source

echniques of measuring and recording the horizontal polar diagrams of irectional radar aerials are now highly developed and make use of both W and pulsed sources in combination with CRT or pen type recorders. n the case of wide aperture aerials, however, observance of the usual ayleigh criterion results in large source to aerial distances and generators f not negligible expense. It, therefore, appeared worthwhile to test the sefulness of the sun as a noise source in this type of measurement, articularly as such a technique would permit observations of the hori- ontal diagram to be made at the various angles of elevation which are of nterest operationally.

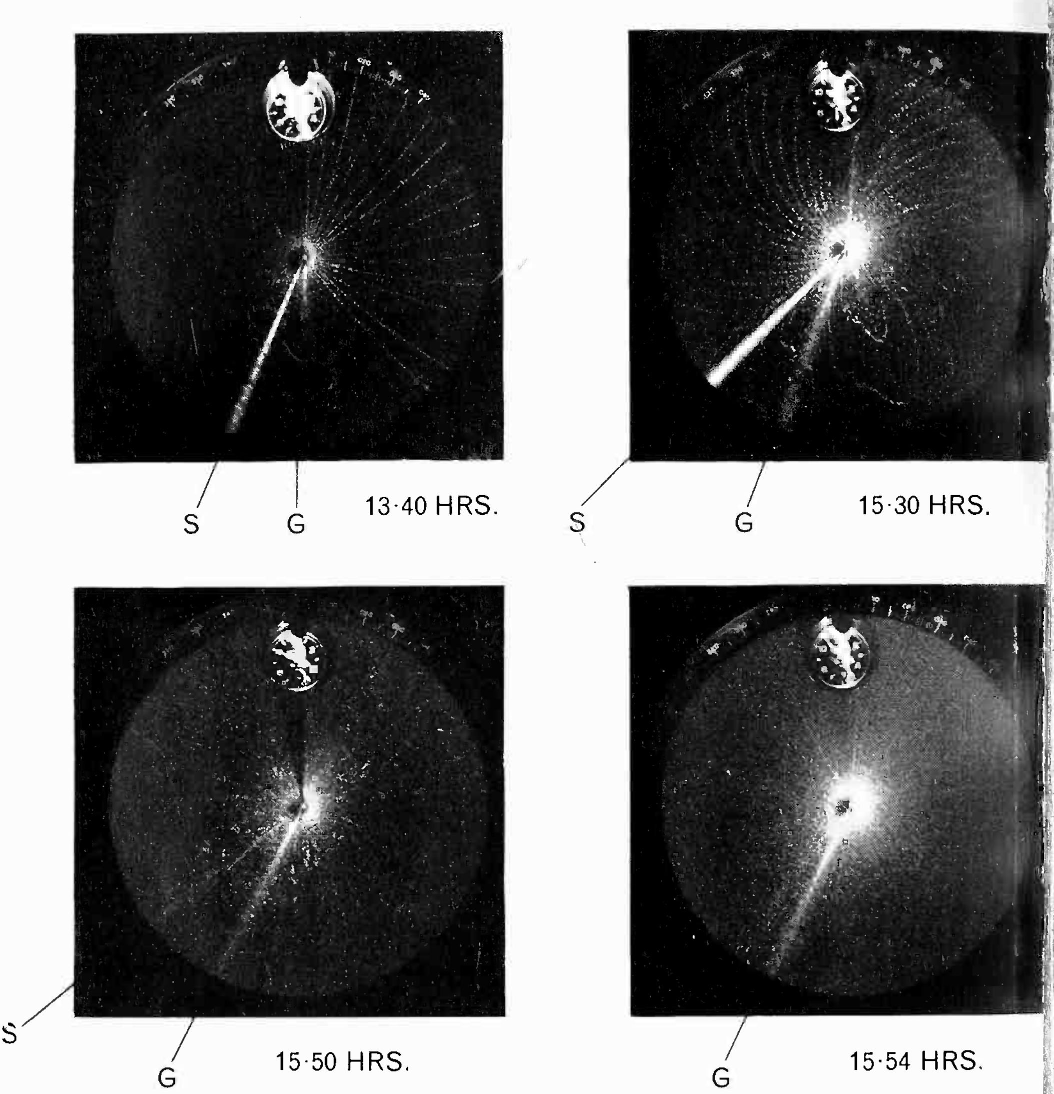

*Fig. 1. Solar noise signal on PPI of metric radar*

The first simple approach was to photograph the PPI response as i Fig. 1, and to make a density plot of the negative using a Hilger recordin densitometer. The record is shown in Fig. 2; a normalized plot of th horizontal pattern of the aerial taken by the usual oscillator method shown for comparison. Substantial agreement between the main lobe will be noted, also the correct positioning of the side lobes. The amplitud of the side lobes relative to the major lobe are clearly in error, and o further consideration it appeared that accurate measurement of side lob amplitude would require correction for (*a*) the smoothing introduced b the sun's movement during the time necessary to build up a PPI pictur

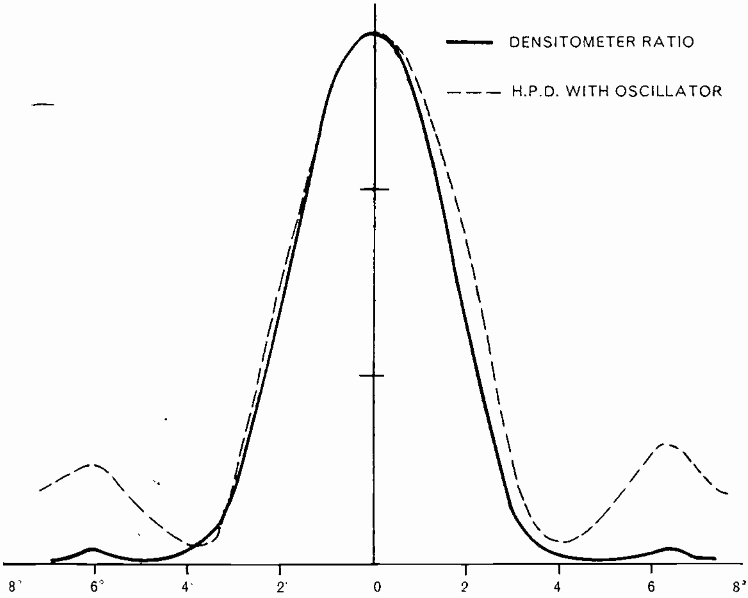

*Fig. 2. Horizontal polar diagram of 215 Mc/s aerial*

sufficient density, (*b*) the finite aperture of sun, (*c*) saturation in the osphor, (*d*) the $\gamma$ characteristic of the film. Solution of these difficulties uld hardly be economic in an application of this type where accurate hniques already exist but the simple photographic method is obviously t without interest.

Later experiments have used a technique developed by Mr. M. H. ffin of the Baddow Laboratories in which the solar noise is integrated ring the trace time, i.e. 4 milli-seconds for 250 pps trace repetition quency, and this integrated signal is applied to the normal sweep amplifier ding the rotating deflection coils of the PPI. The record on the cathode y tube now consists of a sequence of radial lines of length proportional the integrator output. Fig. 3 shows an interesting example of this type record in which the solar noise responses corresponding to frequencies 202·5 Mc/s and 250 Mc/s respectively are derived from two arrays ounted back to back on a common turning gear, and switched automatically to the display every half revolution. (See Fig. 4.)

The same method was also applied to measure the peak signal on ccessive sweeps of the aerial through the sun for the purpose of measuring e radiation diagram of the aerial in the vertical plane. The method has o been used for studying the direction and amplitude of interfering

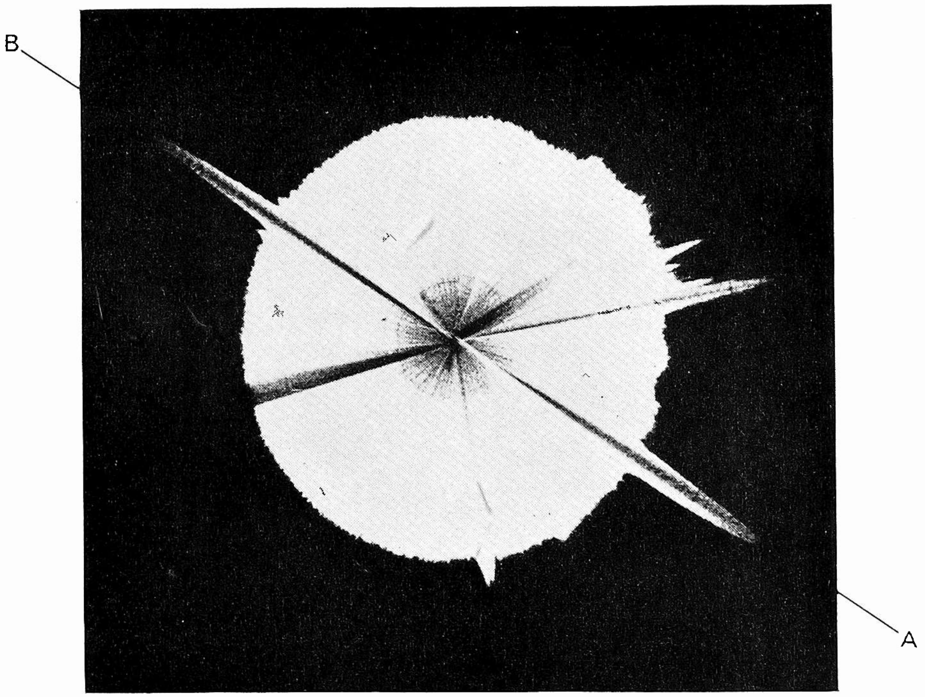

*Fig. 3. Solar noise signals at 202·5 Mc/s and 250 Mc/s*

signals, but applies equally to the sun as shown. The form of the horizonta diagram is again clearly seen and it will be apparent that the peal amplitude can be readily measured for each sweep of the aerial whicl permits the rate of change in amplitude of the solar noise signal with angl of elevation to be measured. The vertical plane radiation diagram calcu lated for the experimental aerial is shown in Fig. 5. It has proved possibl to reproduce the angular positions of the maxima and minima on thi diagram exactly when due allowance has been made for the sun's aperture but the amplitude of the second lobe has tended to appear enhance relative to the first lobe, suggesting attenuation at the lower angle o elevation due to the increased path length through the ionosphere and th atmosphere.

One interesting result which has come out of this work has been th determination of the effective position of the earth reflection plane. Durin the war the GCI stations were used to measure the altitudes of hostil aircraft by the amplitude comparison of signals derived from aerials a different mean heights. It was, therefore, a matter of considerable impor tance to know these aerial heights accurately. It was considered that th effective heights would be a function of the particular soil terrain an ype of cultivation, and so much effort was expended in determining the osition of the earth's effective reflecting surface. Such experiments, lthough widely conducted, were contradictory and it was necessary to ccept, perforce, the height of the arrays as measured in the usual way. he present experiments have employed an infinitely distant source and o were ideally suited to establishing the effective height of the aerial by easurement of the positions of the maxima and minima. These measurements have failed to show a reflection plane which differs from the osition of the earth's surface as ordinarily determined. It should be dded that the site in question is located on flat arable land having a clay ubsoil, and is typical of the wheatlands of Essex.

## olar Noise Signals Observed on Microwave Radars

mprovements in receiver techniques at microwave frequencies combined ith the introduction of the high gain arrays required to provide both the adar cover and resolving power demanded by modern military aircraft,

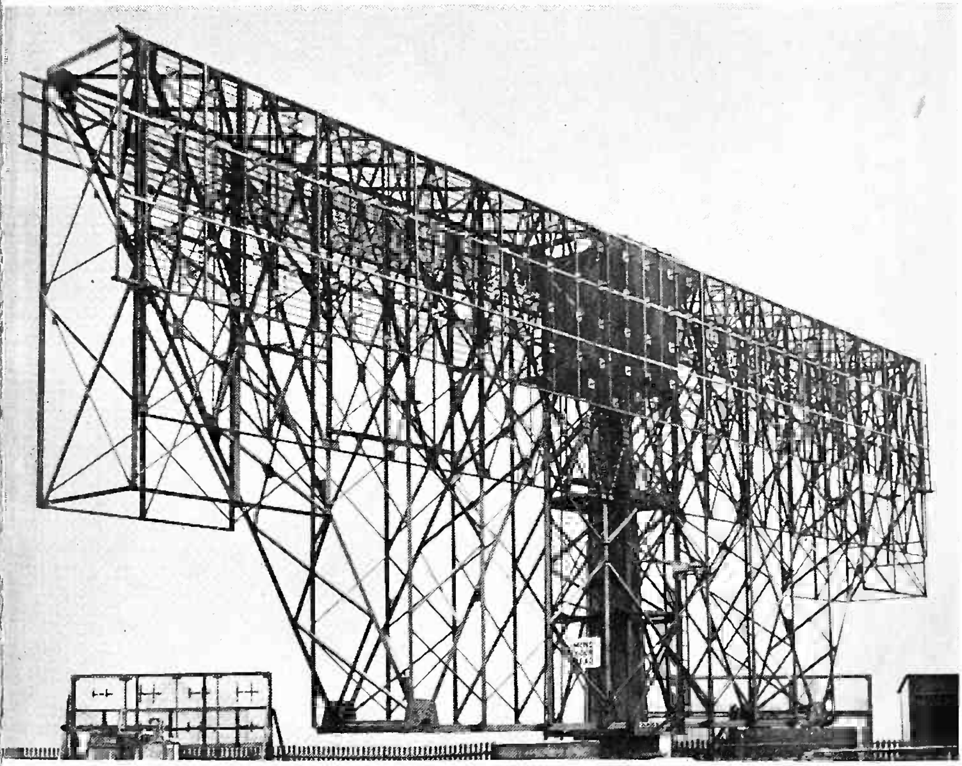

*Fig. 4. Experimental array for metric radar, 202-250 Mc/s*

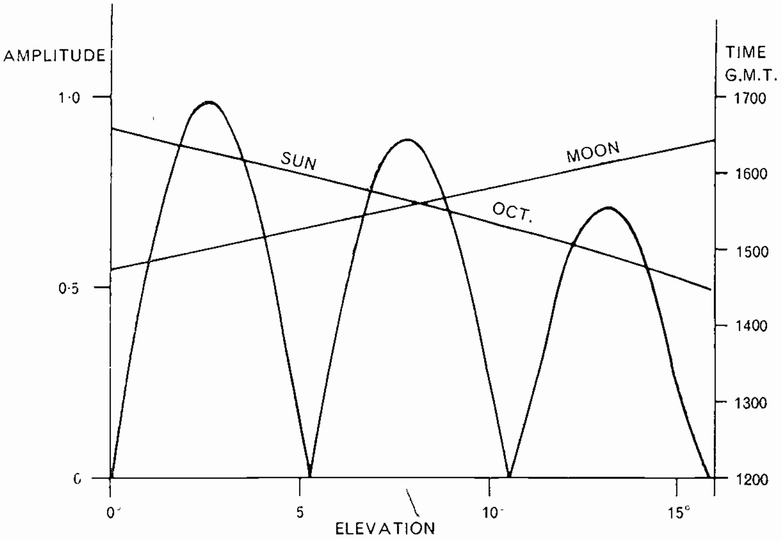

*Fig. 5. Ground reflection interference pattern of four-stack array (215 Mc/s 25′ mean heigh*

have caused the solar noise echo to be a familiar feature of the PPI a sunrise and sunset. Thus, in the case of an S-band nodding height finde the sun's signal is clearly visible on the range-height display shown i Fig. 6. In this particular equipment the aerial gain is 41 dB and th receiver noise figure 9 dB so that the noise power available to the receive on the assumption of black body radiation from the sun with surfac temperature 6,000°K would be 5 dB down on the set noise. Neverthele the solar signal is always visible on this equipment when its azimut corresponds to the bearing of the sun.

Again, in the case of a surveillance L-band equipment the aerial gain 40 dB and the noise figure yielded by the Travelling Wave Tube receiv is 8 dB so that black body radiation from the sun at 6,000°K would al be 5 dB down on the set noise, and a daily solar signal would not b anticipated. In fact, however, the solar noise signal is observed at sunri and sunset every day and is so constant in form and amplitude that careful appreciation has been made of its application in antenna studie

The TWT receiver is normally operated in association with an imag rejection filter, but Fig. 7 shows the noise signal in the PPI with the filt temporarily removed. It will be seen that the signal is divided into tw This apparent splitting is an interesting diffraction grating effect and aris from the dispersive property of the linear array; the signal and its imag differ in frequency by twice the IF and are therefore observed at differe angles. When the image rejection filter is restored into the circuit th image signal disappears from the tube.

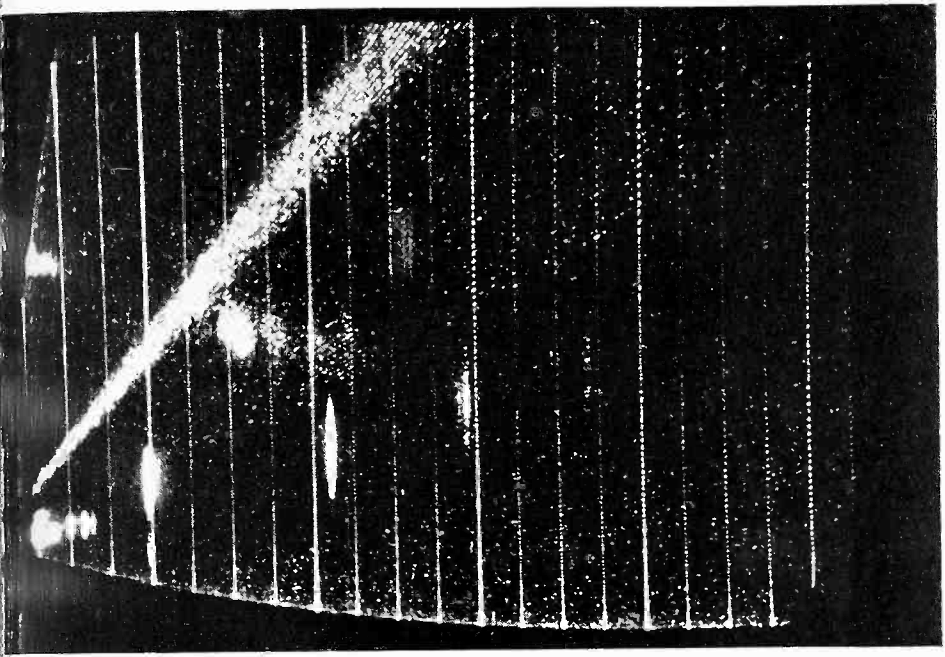

*Fig. 6. S-band solar noise signal as recorded by a nodding height finder*

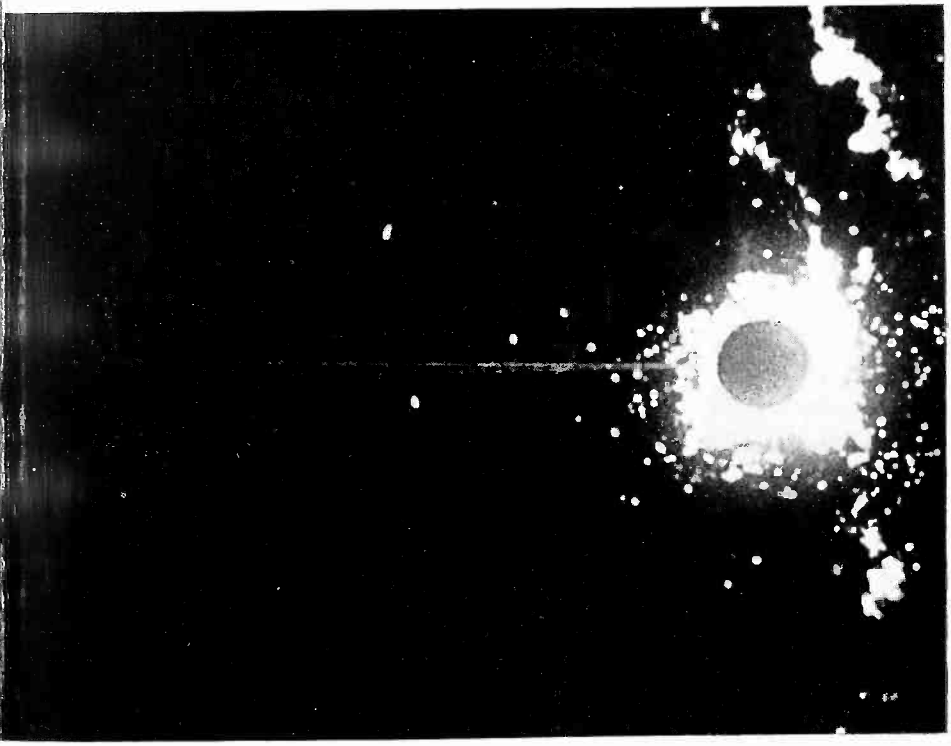

*Fig. 7. L-band solar noise signal on the PPI*

In this particular equipment the horizontal beam width of 39 minutes of arc is comparable with the angle subtended by the sun's disc, but the accuracy with which the horizontal polar diagram of the array can be traced suggests that the effective diameter of the sun as an L-band noise source is considerably less than the 32 minutes of arc of the optical disc. Since the position of the sun is accurately known in elevation and azimuth, it has proved most helpful to use the noise signal in checking the setting up of the radar in azimuth, and this method will surely be of great value at many sites where accurate azimuthal alignment of a radar from a suitably located permanent echo or beacon is difficult. The checking of the absolute elevation accuracy of a nodding height finder is similarly difficult, but in the experimental evaluation of the S-band equipment mentioned above we have found the sun to be an adequate source of signal of known angular elevation as is evidenced by Fig. 6. In this figure the angle scale is greatly expanded which exaggerates the apparent beam width.

## Vertical Polar Diagram Measurements

To those responsible for Air Defence planning, the characteristic of a surveillance or control radar which is of greatest interest is the vertical polar diagram, but measurement of radar performance is unfortunately an operation which is difficult to make accurately, economically, and conveniently. While the horizontal polar diagram of a radar can be plotted without difficulty, the vertical polar diagram is not so easily determined and the difficulty of the measurement increases with the size of the antenna and with the angular extent of the vertical cover which it is desired that the radar system shall provide.

It has appeared in the past that there was no really satisfactory alternative to mounting the array with its normally vertical axis in an horizontal position and so establishing the required diagram as in an ordinary horizontal polar diagram measurement, using a remote oscillator and rotation of the reflector. While this method is satisfactory for small antennas, and we have successfully used this technique for aerials with apertures up to 32′, it requires expensive mounting tackle and great care has to be exercised if the reflector is not to be distorted in the process. For the really wide apertures of modern search radars, the method is prohibitively expensive.

An alternative approach is to explore the diagram yielded by the centre section only of the array mounted in the above manner. In the case of a linear array, feeding into a cylindrical reflector, this method would appear to be reasonably satisfactory, but for a double curvature reflector it is obviously less so.

In our experimental evaluation of large antennas we have also made use of CW oscillators carried by captive balloons and by helicopter, but the rk has been slow and tedious and has required much repetition in order invest the result with significance. In particular, the observations to be de in the high angle cover region have required the source to be brought ich too close to the antenna, and so the accuracy of measurement has en prejudiced in that part of the cover which it is most desired to plore, in order to confirm that the optimum power distribution and sitioning of a primary feed have been achieved.

It is ultimately necessary to resort to controlled test flights with aircraft, t while such flights are inevitable in order to establish the final perfor- nce diagram of the complete system, it is most undesirable to use craft flights for antenna polar diagram measurements.

The observations described in the preceding section had shown that a ise signal could be received from the quiet sun by a microwave radar, d was of sufficient intensity to permit accurate measurements to be de of the variation of signal amplitude with angle of elevation of the n. It was thus an obvious step to explore the possibility of using the sun a standard noise source for the exploration of radar aerial vertical polar grams.

In the experimental evaluation of a large L-band antenna the amplitude the solar noise signal has been measured and recorded photographically, ng the integrator and radial scan technique described earlier, also using acked-off diode with current amplitude displayed on a long persistance T. The noise amplitude has been recorded against time, which has rmitted correlation with the known angle of elevation of the sun. ll details of the measuring technique finally adopted are given in an icle appearing on page 21 of this issue of *The Marconi Review* by . M. H. Scanlan.(6)

The measurements have been taken over a number of days in both the rning and evening and have proved to be remarkably reproducible. Fig. 8 is shown a plot of the solar noise signal against the angle of vation for an array of 25′ vertical aperture designed to provide a ecant squared pattern. Also plotted in the figure are the two vertical ar diagram curves derived respectively from the aircraft trials of the nplete radar and from oscillator measurements on a section of the lindrical reflector of this radar, when mounted horizontally on a ntable.

The general correlation between the measurements on the aerial section d on the solar signal is good, and much superior to the results obtained h captive balloon and helicopter borne oscillators. The agreement tween the solar noise curve and that resulting from the aircraft test hts is reasonably satisfactory at low angles of elevation, but shows nificant discrepancies at high angles. Further detailed work has shown

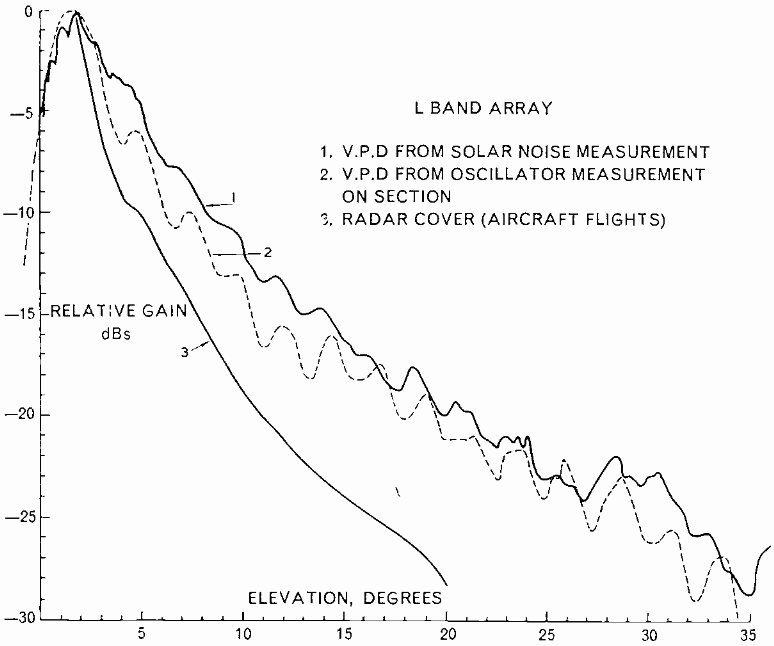

*Fig. 8. Vertical polar diagram of L-band array*

that a satisfactory explanation of these differences is to be found in th scattering diagram associated with the particular test aircraft.

The solar noise method is thus clearly established as a reproducibl accurate, and economic technique for exploring the radiation patterns microwave aerials in those cases where the total gain of the antenna such as to provide a signal of adequate amplitude; it is especially suite to the S and L-band surveillance radars of today.

It is well known that the vertical aperture of a microwave radar ca never be such as to provide a bottom edge to the pattern, so sharp as eliminate completely the possibility of a ground interference pattern. Th solar noise method fails to reveal the detail of such a pattern, since th angular aperture of the solar disc is wide compared to the interferen lobes. In consequence, the interference pattern is smoothed out. The sol noise method, however, does permit the low elevation pattern to b explored for different azimuths of sunrise and sunset, and so allows th effect of the terrain to be assessed.

## Galactic Noise Observations on a Metric Radar

The PPI records reproduced in Fig. 1 clearly show the diurnal motion the solar noise signal marked with an S. The photographs also show th esence of a second signal marked G which also partakes of the same urnal motion as the sun's signal, but continues to be visible on the tube ng after the sun has set.

Observations were taken over a period of a month and showed that the signal was losing in azimuth relative to the G-signal by about 1° per y. From the difference in right ascension of the sun and this unknown urce, also from the polar diagram of Fig. 5, it was recognized that this nal was indeed coming from the general direction of the galactic centre. is detection of noise from the galaxy is not, of course, novel, but it is teresting and remarkable to see Jansky's original observation reproduced simply and directly upon a radar PPI; the maximum intensity of the ygnus source at a frequency of 160 Mc/s corresponds to a flux of $5 \times 10^{-17}$ atts/sq.m/Mc/s at the earth's surface(7).

## Radio Moonshine" at 215 Mc/s

n the afternoon of Thursday, October 27th 1955, a test flight programme as in progress to establish the performance of the 215 Mc/s radar scribed in an earlier paragraph. The tests were being conducted by r. G. F. Slack, Mr. R. F. O'Neill and the author. The presence of a solar oise signal having the appearance of Fig. 1 upon the PPI when the sun's evation correspond to the lower lobes of the radiation diagram, was a henomenon with which we were thoroughly familiar. Reference to Fig. 5 ill show that on the date in question the sun would be passing through he centre of the third lobe at approximately 14.45 hours. We did not sually see the sun in the third lobe, but on this occasion a signal was seen hich expanded in azimuth to fill 90° of the tube face by the time the sun as in the maximum of the first lobe, i.e., about 4 p.m. From the detailed easurements of the horizontal polar diagram it was concluded that the oise power centred on 215 Mc/s received from the active sun for a short eriod on this date was at least 25 dB above the level normally received.

Confirmation of this state of the sun was received on the subsequent ays when transatlantic communications were reported disrupted by the rrival at the earth of the corpuscles emitted by the active sun. Further vidence was also provided by routine measurements of solar noise at 75 Mc/s made at certain radio-astronomical laboratories. These results uggested that the sun's activity was about 23 dB above normal. In ddition short duration peaks were recorded superimposed on the enhanced oise background, and which rose to 10 dB or more above the mean level(8).

For a brief time during the period 15.20-16.00 of this day a noise signal as observed to paint upon the PPI along a south easterly bearing. This ignal was very faint indeed but persisted over about twenty sweeps of he aerial (five minutes). Preoccupation with the test flight prevented careful observation of this noise signal, except to make a rough tracing on paper of its position relative to the angular centre of the sun's signal Visual observation of the moon on conclusion of the flight showed it to be in the same general direction as had been noted for the strange noise signal, and so the possibility was recognized that this signal might resul from reflection from the moon of the enhanced noises radiation from the sun, i.e., that "radio moonshine" on 215 Mc/s had been observed.

Measurement of the above tracing returned an angle of 134° for th angular position of the unknown signal relative to the sun's bearing Extraction of the corresponding angle for the moon from the Nautica Almanac for the approximate time in question gave 135·2°. This was rather exciting agreement having regard to the crudeness of the tracing and the difficulty of estimating the axis of the solar signal upon the PPI

Much the best test of the lunar origin of the signal would have been to have measured the time variation of the bearing, but the short duration of the signal and preoccupation with the test flight prevented this. In the absence of this information we can only try to estimate the relative amplitudes of the "lunar" and solar signals and then compare thei ratio with the attenuation that might be produced by the lunar path o transmission.

As noted earlier, the average level of the solar signal on the afternoon of October 27th 1955, was in the order of 25 dB above the level normally prevailing which is usually about 10 dB above set noise. The "moon" signal was only about 1 dB above set noise, thus this signal as seen on the PPI was 34 dB down on the solar signal. A further attenuation factor arises on account of the different angle of elevation of the sun and moon at the moment in question and with respect to the vertical diagram of the array. On Fig. 5 are plotted the angle of elevation—time curves for the sun and moon respectively. It will be seen that over the period 15.20-16.00 hours there is a wide uncertainty as to the effect of the antenna gain function in the vertical plane, but the curves clearly suggest that it was most unlikely that the ratio could have exceeded 20 dB.

These considerations indicate that the "moon" signal as presented to the antenna could not have been more than 54 dB down on the solar signa and may well have been only 34 dB down having regard to the symmetry of the sun and moon curves of Fig. 5, relative to the second lobe. It remains to examine whether these ratios could be compatible with the attenuation introduced by the moon path.

The intensity of the solar flux presented to the moon at any instant is sensibly equal to that obtaining at the earth and so the attenuation introduced by the moon reflection appears as $10 \log \frac{\sigma}{4\pi R^2}$ dB; where $\sigma$ is the choing area of the moon in square metres and $R$ metres is the distance of he moon from the earth.

If we assume that the reflectivity of the moon is unity and that all the nergy incident upon it is radiated isotropically, then $\sigma = \pi r^2$, where $r$ s the radius of the moon. We have, for the attenuation, 10 log $\frac{\pi r^2}{4 \pi R^2}$, with $r = 1{,}080$ m and $R = 230{,}000$ m; this leads to a value of 52 dB.

A recent survey of information on the radio reflection coefficient of the moon given by Dr. F. Graham Smith (9) at the I.A.U./U.R.S.I. Conference (1959) showed that the cross section of the moon is about $\cdot 1\pi r^2$. The attenuation in this case is then 62 dB.

If the higher echoing area of the moon be taken, the calculated attenuation of 52 dB suggests that the lunar reflection of the enhanced solar noise could have yielded a detectable signal on the PPI when the moon was at the elevation corresponding to the maximum of the second lobe. The attenuation figure of 62 dB exceeds the upper limit of the signal ratio by 8 dB. Under these circumstances the moon could have yielded a reflected signal detectable on the PPI only during a burst of solar noise above the enhanced level. Such short duration bursts do indeed occur.

Taking the evidence as a whole, viz., correct bearing of the moon, enhanced sun, freedom of the site from spurious reflection and finally the polar diagram effects, it appears likely that the noise signal of unknown origin observed on October 17th 1955 was due to reflection by the moon of the noise radiated by the sun. This evidence is certainly not conclusive, although much superior to that advanced by Steinberg and Zisler in 1949(10) who claimed confirmation of a lunar reflection even though the noise signal was only 18 dB down on that from the sun. "Radio moonshine" is indeed difficult to detect and measure—which is perhaps only to be expected; perhaps our work will help to make a future identification of moon reflections more likely by concentrating attenuation on possible lunar reflections during solar bursts. Errors such as those of Steinberg and Zisler(10) or of Kraus(11) would then be avoided. It should then be possible to obtain information on the nature of the moon's surface by observing the reflection coefficient over a band of frequencies.

## Observations at 1,300 Mc/s on the Enhanced Sun; Auroral Effects

The performance of an L-band radar against a solar noise signal has already been discussed; the sun is clearly shown on the PPI at sunrise and

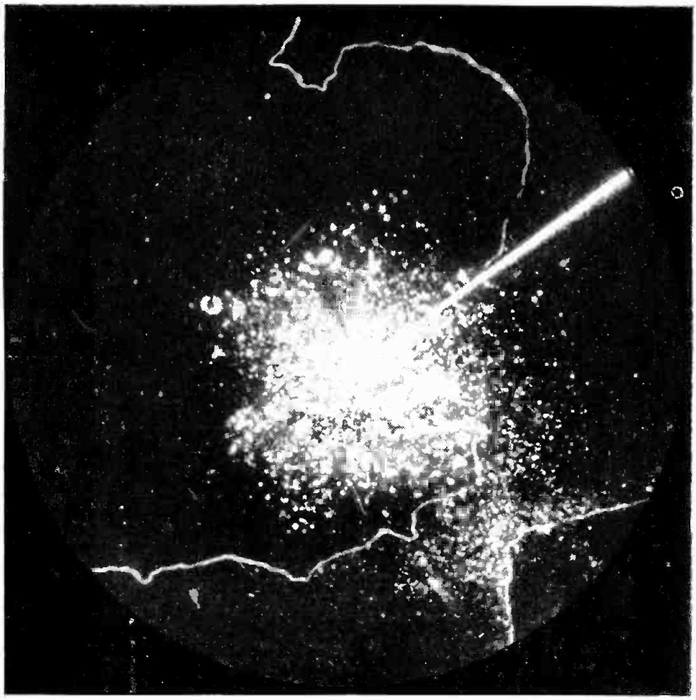

*Fig. 9a. Enhanced solar noise at 1,300 Mc/s*

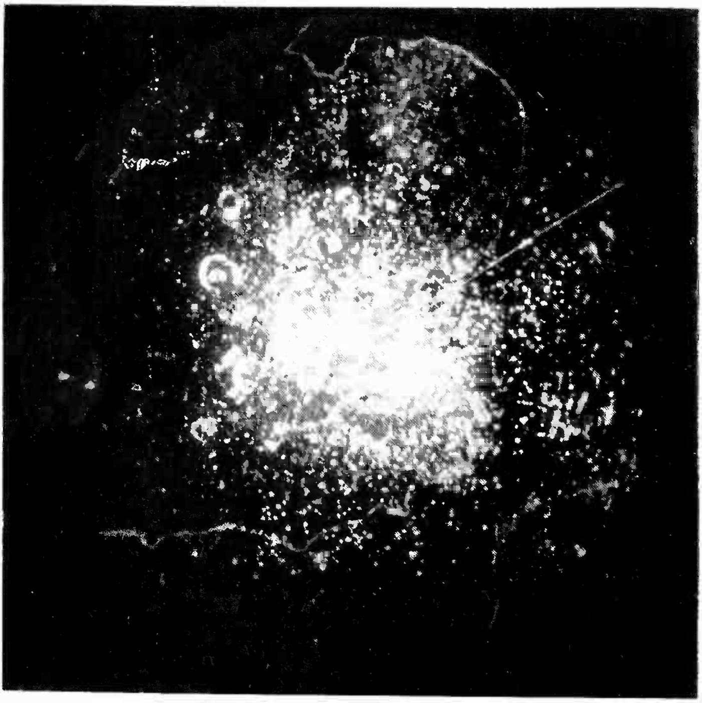

*Fig. 9b. Normal solar noise at 1,300 Mc/s*

unset when its elevation corresponds to the peak in the radiation diagram of the antenna.

During sunrise observations conducted on July 14th 1959, the radial noise paint from the sun was particularly intense. This enhancement of the solar noise signal is shown in Fig. 9. The sun was visible on the PPI for a period of 1 hour 20 minutes, as compared to the usual time of 40 minutes for this period of the year. From a knowledge of the sun's elevation and the curves given in Fig. 8, it was concluded that the sun was displaying an activity of 15 dB above the normal.

As discussed in the preceding section, such an outburst of intensive solar activity is followed by disruption of radio communications on the earth. The noise emitted by the sun travels with the velocity of light, but the charged particles which are simultaneously ejected travel much slower and only arrive at the earth some 6 to 30 hours after the disturbance. On arrival the particles interact with the earth's magnetic field and tend to stream into the upper atmosphere in the general region of the geomagnetic poles. In the descent from the upper atmosphere these high energy particles create channels of ionization. It is during the later recombination processes that the optical emissions are produced which constitute the aurora. The

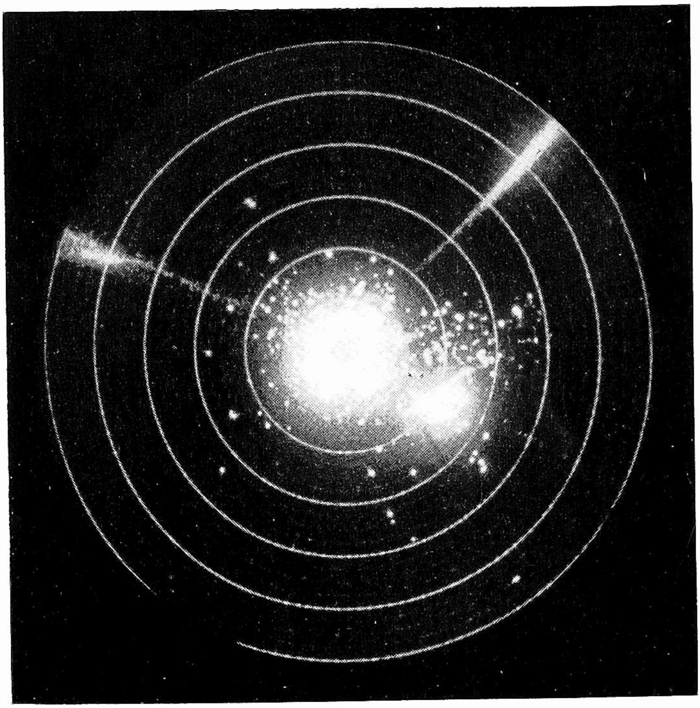

*Fig. 10. Auroral effect on L-band radar*

randomness of these electron processes also ensure that radio noise emitted, while the presence of the electron cloud with densities of up t $10^8$ electrons per c.c. permits radar scattering.

On the afternoon of July 15th 1959, i.e., 34 hours following the sola burst reported above, anomalous echoes were observed upon the PPI of th L-band radar. The tube was photographed by Mr. J. D. Bell and Fig. 1 reproduces one of the cine frames. There can be little doubt that the effect recorded on this picture are due to auroral scattering, the aurora havin been produced by arrival of the particles emitted during the solar eruptio of the previous day.

## Acknowledgements

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## References

1 K. Jansky: *Proc. Inst. Rad. Eng. 20*, 1920, 1932; *21*, 1387, 1933; *23*, 1158, 1935; 2 1517, 1937.
2 G. Reber: *Astrophys. Jr. 91*, 621, 1940; *100*, 279, 1944.
3 G. C. Southworth: *Jr. Franklin Inst. 239*, 285, 1945.
4 E. V. Appleton and J. S. Hey: *Phil. Mag. 37*, 73, 1946.
5 B. Lovell and J. A. Clegg: *Radio Astronomy*, 1st Ed., p. 169. Chapman and Hall London, 1952.
6 M. H. Scanlan: *Marconi Review.*
7 B. Lovell and J. A. Clegg: *loc. cit.* p. 187.
8 Personal Communication from Cambridge Radio Astronomical Laboratory (1959).
9 Personal Communication from Dr. F. Graham Smith (1959).
10 J. L. Steinberg and S. Zisler: *Comtes rendus de l'Academie des Sciences, 229*, 811, 1949
11 J. D. Kraus: *Nature, 178*, 159, 1956.

# SOME MEASUREMENTS ON RADAR AERIALS, USING STELLAR NOISE

By M. J. B. SCANLAN, B.Sc, A.R.C.S.

*The measurement of the radiation patterns, especially in the vertical plane, of arge radar aerials is often a matter of considerable difficulty. Work with cale models or with sections of an array can give some guidance, especially n the design stage, but some check upon the complete aerial is often felt to be esirable. Test flights are costly, tedious and often inconclusive, since they nvolve the aircraft echoing area, which may vary rapidly with aspect and ngle of elevation, and which in any case has only a statistical significance. t is thus difficult to correlate results obtained in this way with scale model or ection experiments. Another method is therefore required, and is in fact eadily available. This uses solar noise radiation as a test signal, and has been sed with great success, requiring only readily available apparatus to give a reat deal of the required information. A short account of the sun as a noise ource is given here, together with a description of the experiments so far arried out, and an indication of how sensitivity can be improved, using radio astronomy techniques.*

## The Sun as a Noise Source

Since Southworth's first observations on the sun as a microwave source n 1942 (ten years after Jansky had founded radio astronomy), a vast mass f data has been accumulated showing that the sun's radio spectrum is very complex, not easily to be summarized in a short article. However, f we are interested only in wavelengths commonly used in radar, say rom 3 to 50 cms, it is perhaps possible to give a reasonably simple account, which does not, however, pretend to replace the comprehensive surveys available elsewhere(¹).

Continuous recordings of solar radiation at many frequencies are made at various observatories; examples from 1948 are given by Pawsey and Bracewell(¹), and some 1958 observations at 2,800 Mc/s(²) are shown in Fig. 1. Such records enable two components in the microwave solar spectrum to be distinguished. There is firstly the quiet sun component, given by the minima of the fluctuations. This is thermal radiation originating in the corona at temperatures much higher than that of the photosphere. The power radiated varies by a factor of two or three from sun spot minimum to maximum: if the sun were a black body, of the size of the photosphere, the temperature required to give the quiet sun component at sun spot minimum is given very roughly by

$$T_d = 4 \times 10^5 \lambda \qquad (1$$

where $T_d$ is in degrees and $\lambda$ is in metres

For example, measurements in England and in Canada on the same da in 1954 gave temperatures of 42,200° and 43,300° at 10·8 cms(³). Th spectrum of the quiet sun is also shown in Fig. 7.

Over and above the quiet sun component, Fig. 1 shows the presence o the so-called slowly varying component. This has an irregular period o rather less than a month and is in general roughly equal at its maximun power to the quiet sun component. This flux variation is seen to be wel correlated in period and amplitude with sun spot activity and is though to have a thermal origin in disturbances associated with the spots. Sinc the area covered by spots is very small (a few thousandths of the sun' disc) the effective temperature of the disturbances (if the effect is indee thermal) is clearly very high.

A third type of solar emission may be distinguished, namely " bursts." Three classes of " bursts " may be distinguished(¹): those associated wit flares, noise storms associated with sunspots, and isolated bursts with n certain optical counterpart. Of these only the first need concern us here since the other two are restricted to metric wavelengths. This type o

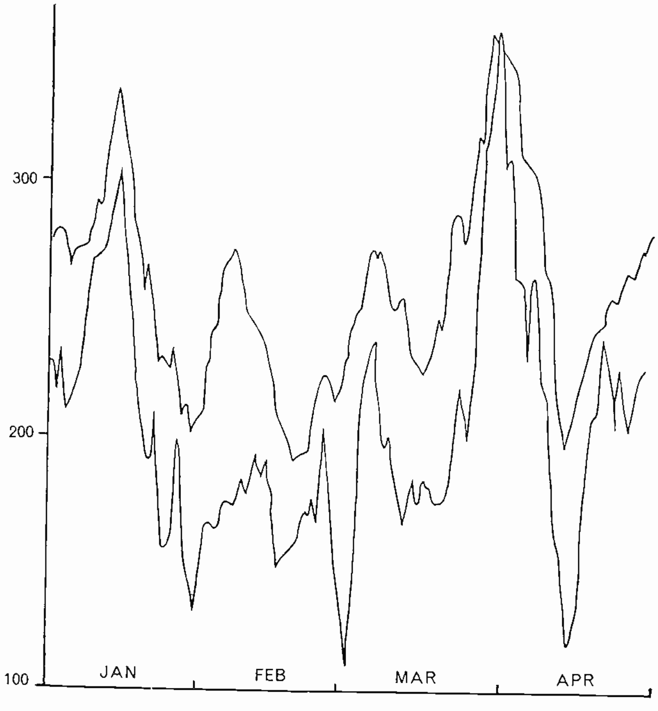


*Fig. 1. 2,800 Mc/s solar Flux (units $10^{-22}$ watts $m^{-2}$ (c/s)$^{-1}$) and Zurich Sun Spot Numbe (lower curve) for 1958*

urst is shortlived (a few minutes only in general), but may be very tense, especially at the longer wavelengths; fortunately, very large solar ares are rare, even at sunspot maximum.

It will be clear, even from the oversimplified discussion given so far, hat the sun cannot be regarded as a black body radiator. Nevertheless, is often convenient to treat it as such, and to use the Rayleigh-Jeans rmula to connect the power received with the apparent disc temperature. rom the size of the sun, and of the earth's orbit around it, it is easily hown that the power flux $S$ received on either polarization at wavelength is given by

$$S = \frac{0{\cdot}94 \times 10^{-27} T_{\mathrm{d}}}{\lambda^2} \text{ watts meters}^{-2}\ (\text{c/s})^{-1} \qquad (2)$$

here $T_{\mathrm{d}}$ is the apparent disc temperature which is given roughly by (1) r the quiet sun at sunspot minimum. It should be remembered, however, hat (1) underestimates the temperature, perhaps by six times or more, hen the slowly varying component and the sun spot cycle are both at aximum.

## he Detection of Solar Noise

he noise power due to the receiver and aerial may be expressed as

$$p = k[(N - 1)\, T_0 + T_{\mathrm{A}}] \text{ watts } (\text{c/s})^{-1} \qquad (3)$$

here $k$ is Boltzmann's constant, $N$ is the receiver noise factor, $T_0$ and $T_{\mathrm{A}}$ re the room and aerial temperatures. A measurement of noise factor gives , while the change in noise output when the receiver is connected to the erial and to a matched termination at room temperature gives $T_{\mathrm{A}}$. ence $p$ is known: for centimetric radar receivers and aerials at present in se, its value cannot be much less than $2 \times 10^{-20}$ watts $(\text{c/s})^{-1}$, since $N$ typically about 5 and $T_{\mathrm{A}}$ about 100-200°K. This situation, in which e noise factor is dominant, may be overcome by the advent of masers nd parametric amplifiers. It is unfortunate that, since the larger radar erials " see " the ground and the atmosphere, the aerial temperature is igher than if they looked into space, so that the advantage of a very low oise receiver is to some extent lost. Masers have already been used in adio astronomy(4) but it seems doubtful, for radar aerials at least, if the reatly increased complexity, as compared with a parametric amplifier, is orth while.

Given a receiver noise power of $2 \times 10^{-20}$ watts $(\text{c/s})^{-1}$ what is the inimum detectable signal? In the absence of gain fluctuations, this epends on the receiver bandwidths before and after the detector. A large re-detector bandwidth and a narrow post detector bandwidth give the average value of a large number of random noise events, which are therefore smoothed out. The smoothing factor is the square root of the ratio of the bandwidths and can easily have a value 1,000, enabling a signal of $2 \times 10^{-23}$ watts $(c/s)^{-1}$ to be theoretically detectable. If this figure is to be realized, however, the gain of the receiver must be held constant to better than 0·1%; gain fluctuations, even with the greatest care over power supplies, are in fact the limiting factor in the sensitivity of so-called straight systems. Apart from this limitation, the bandwidth desiderata outlined above may conflict with a requirement to measure the variation of a phenomenon with time or with frequency.

The gain stability limitation can be considerably eased by radiometer techniques, originally used by Dicke(5). Here, the receiver is switched rapidly (say thirty times a second) between the aerial and a matched termination, so that (if these have the same temperature) only gain fluctuations at the switching frequency, which are much smaller than in a straight system, are recorded. The Dicke radiometer is widely used in radio astronomy, especially at the shorter wavelengths: it has perhaps reached a peak in the work of Drake and Ewen(6) who were able to detect changes of 0·01° in aerial temperature, although their receiver had a rather poor noise factor.

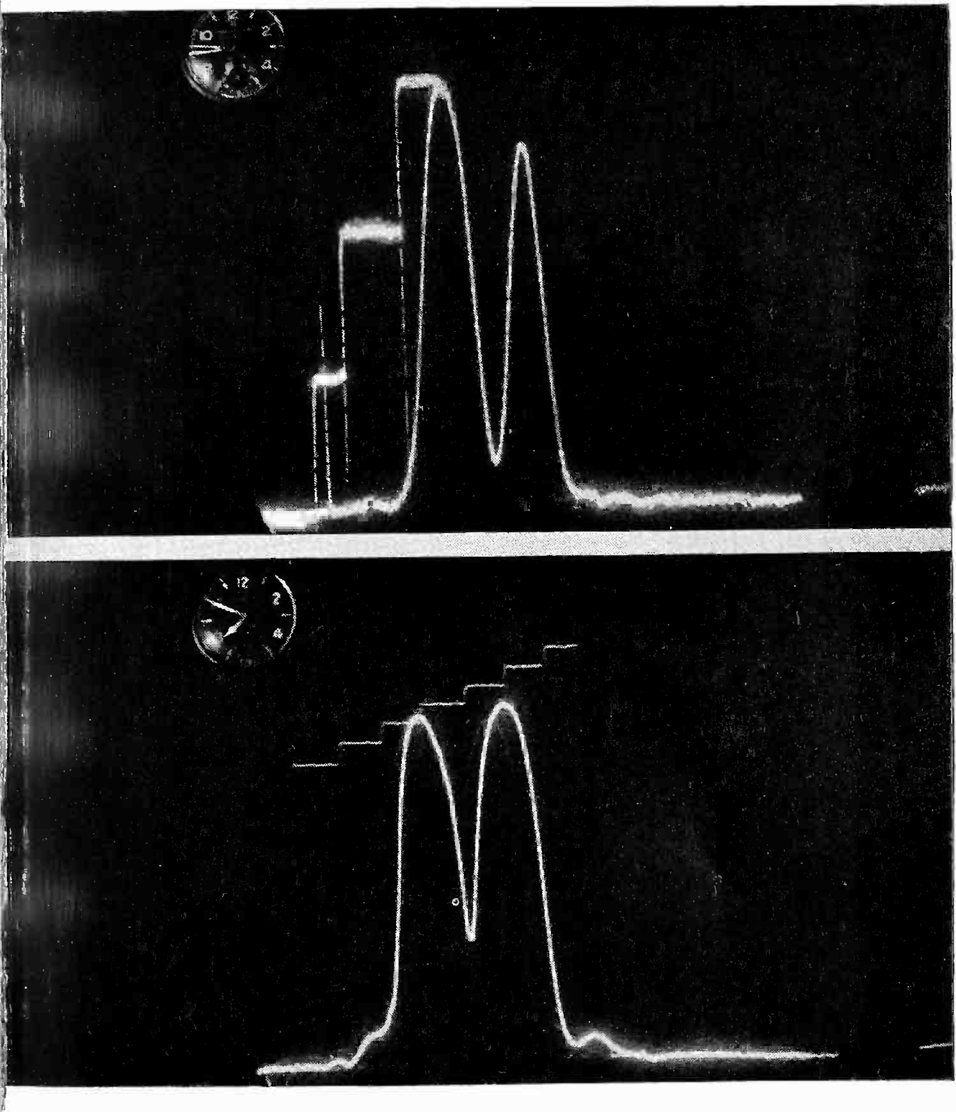
A variation of Dicke's technique by Ryle and Vonberg(7) is mainly used at metric wavelengths and will not be discussed here.

It is fortunately true that the sun is so powerful a source that a straight system will often give polar diagrams of great value, especially when, as now, the disc temperature is considerably higher than the minimum value given by(1); for example at $\lambda = 10$ cms, the power received from the quiet sun, is from (1) and (2), about $4 \times 10^{-21}$ watts meter$^{-2}$ $(c/s)^{-1}$, so that an aerial of effective aperture 1 metre$^{2}$ will collect a signal about 20% of the receiver noise, several times the minimum detectable signal even with a straight system.

## Some Measurements Using Solar Noise

After considerable time and effort had been expended on the measurement of the vertical polar diagram of a large radar aerial by means of test flights with rather equivocal results, attenuation was turned to the possibility of using solar noise, which was readily visible on the displays every day, as a test signal. Preliminary calculations were based on figures given by Ryle(8), and showed that more of the polar diagram would be measurable than was available from test flights, where high angle results were limited by permanent echoes. The first experiments led to a few minor modifications, mainly aimed at greater convenience and speed, and the final experimental method was as follows. Preliminary calculations were made and graphs drawn of the sun's elevation and azimuth for the w hours before sunset: the accuracy required is not great (say 1/10° in evation and 1° in bearing) and daily calculation of a few points was referred to the use of tables, none of which list low angles of elevation. he graphs of the sun's azimuth were mainly of use in searching for the rst weak signals as the sun came down into the beam: the elevation urves are, of course, required for the final vertical polar diagram results.

The receiver used was a normal radar receiver consisting of a broadband



*ig. 2. Sun signals received as the aerial beam sweeps through the sun's azimuth. Sun's evation 12° (upper) and 2·6°. Also visible are 1 dB calibration markers, and (lower photo) side lobes of the horizontal polar diagram*

crystal mixer followed by a high gain IF amplifier and a crystal detector. Noise factor and aerial noise experiments gave a noise temperature of 1,000° at the receiver input. A proposal to put the receiver at the end of the aerial's linear array rather than below the rotating joint in an effort to save the losses (about 1/2 dB) in the joint and associated waveguide runs, was not carried out, as vibration effects and loss of flexibility offset the small advantage to be gained. An increase in IF bandwidth, while obviously desirable to reduce noise fluctuations, was judged not to be worth while: on the other hand, considerable care was taken with power supplies to the receiver in an effort to reduce gain fluctuations. The AC mains were regulated before going to stabilized power packs for HT supplies, and 6 volt batteries were used for valve heaters, firstly for the head amplifier only, finally for all receiver heaters.

The receiver second detector current was used as a measure of received signal. At first, the standing current was backed off and any increase used to deflect a sensitive galvanometer; later the detector output was fed to a DC amplifier, whose output was taken to a pen recorder and to an A-scope. The A-scope, equipped with a slow time-base and an afterglow tube, was photographed during every sweep of the aerial through the sun's azimuth, while the pen record was used only as a check and for identification purposes. Typical A-scope photographs are shown in Fig. 2: They show the increase in signal received (in the form of a horizontal polar diagram of the aerial) as the aerial is swept through the sun's azimuth. The double

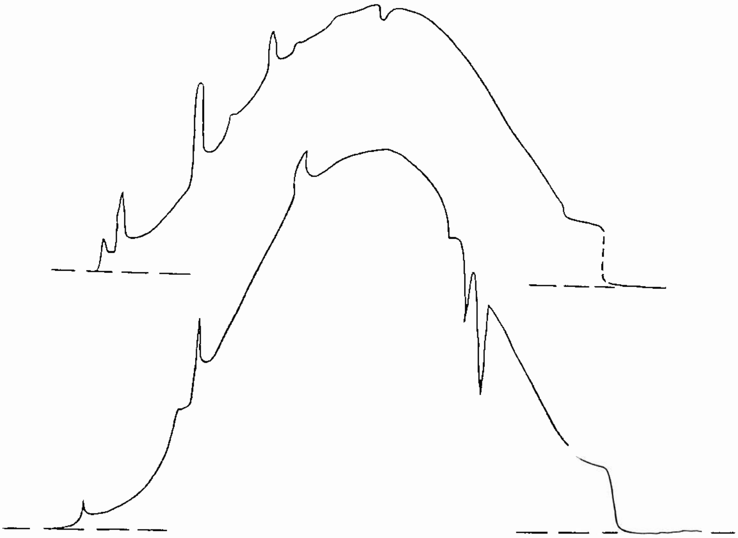


*Fig. 3. Pen recordings of sun signals with aerial stationary. Departures from smooth curves are caused by vibrations of aerial in wind*

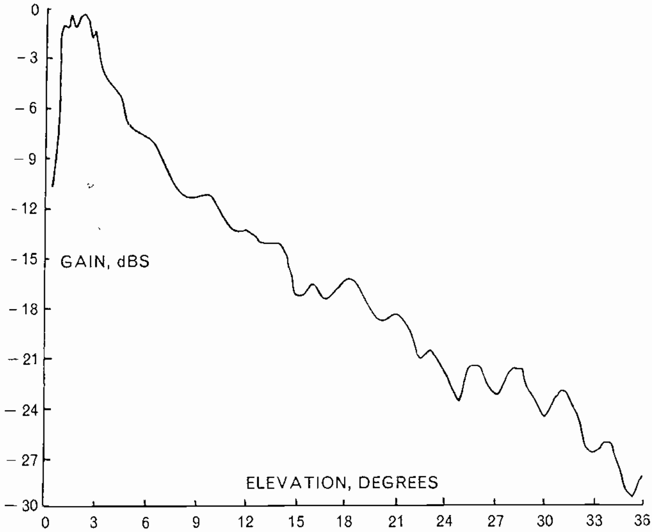


*Fig. 4. The vertical polar diagram of a radar aerial, measured using solar noise*

peaks result from the combination of a linear array, whose "squint" depends on frequency, and a superhet receiver with no RF stage. Calibration of the system was conveniently achieved by increasing the gain in 1 dB steps (using an IF attenuator between the head and main amplifiers) at frequent intervals: such 1 dB calibration steps are easily visible in Fig. 2. The validity of the calibration is easily checked by the injection of a known amount of noise. It was found that photographs could easily be taken at 30 second intervals, if required, corresponding to a change in elevation of about 0·1°. It would not be difficult to reduce this interval, which, however, is probably small enough for most purposes.

Two tracings of pen recordings are shown in Fig. 3. These were taken as the sun moved through the stationary aerial, and each record covers five minutes or so. The small excrescences on the curves are presumably due to slight shifts or vibrations of the aerial in the wind.

Calculation of results is easy if laborious. Each photograph gives the time (and hence the sun's elevation) and a deflection due to the sun's noise. These deflections are easily converted, via the calibration marks, to relative power received, which is proportional to aerial gain, provided that the sun's noise output is constant during the experiment. Any significant contravention of this condition (due to a burst) may well be obvious from the results but is easily eliminated in any case by a repeat experiment on another day. Fig. 4 shows a vertical polar diagram taken in this way in May 1958. It differs from another curve taken the next day by a maximum of about 1 dB. Such close correspondence gives great confidence that the random errors, at least, have been largely eliminated.

## Some Measurements at 600 Mc/s

The experiments so far reported involved a fairly elaborate system, most of which is nevertheless readily available on radar sites. However, in November 1958 a requirement arose to measure, and compare, the vertical polar diagrams of two 600 Mc/s radar aerials on a rather remote and less well equipped site. In this case, the aerials were turned by hand, the rising sun was used (the aerials were obscured when looking towards the setting sun) and the equipment was simple, almost crude. It consisted of the normal radar receiver with its second detector current backed off to zero. Any noise signal was observed as a deflection on a sensitive microammeter. The conditions of the experiment are reflected in the results which show that the low angle measurements are missing in both cases; this was caused by poor visibility, lack of bearing information, and a signal so much larger than expected that it was at first taken for interference. Unfortunately there was no opportunity to repeat the measurements. The results (Fig. 5) show the earth reflection patterns of the aerials very well and agree with theoretical predictions based on aerial aperture and mean height.

## Measurement of Aerial Gain

The measurements discussed so far do not require a knowledge of the sun's temperature, but only that this be constant for the duration of an experiment. A measurement (using solar noise) of the gain of a large radar aerial, on the other hand, does require a knowledge of the sun's temperature, which may be obtained at some frequencies from the published figures (which are always well in arrear) or failing this, from a measurement with an aerial of known gain. This method, of course, amounts to a comparison of the gain to be measured with the known gain, with the sun as signal source, so that its temperature need never be calculated explicitly. It has already been pointed out that an aerial of very modest size will gather enough signal to give reasonable accuracy and the problem of making a microwave aerial of known gain has been dealt with by several authors(9). Since the comparison standard aerial will be relatively small, less accuracy will be required in pointing it at the sun than with a larger array. On the other hand, care must be taken that the sun is sufficiently high for ground reflection effects to be neglected, which may mean that the main array and the gain standard cannot receive strong sun signals simultaneously.

In order to check the gain of the large aerial whose vertical polar diagram is given by Fig. 4, a gain horn was made having a gain of 20 dBs.

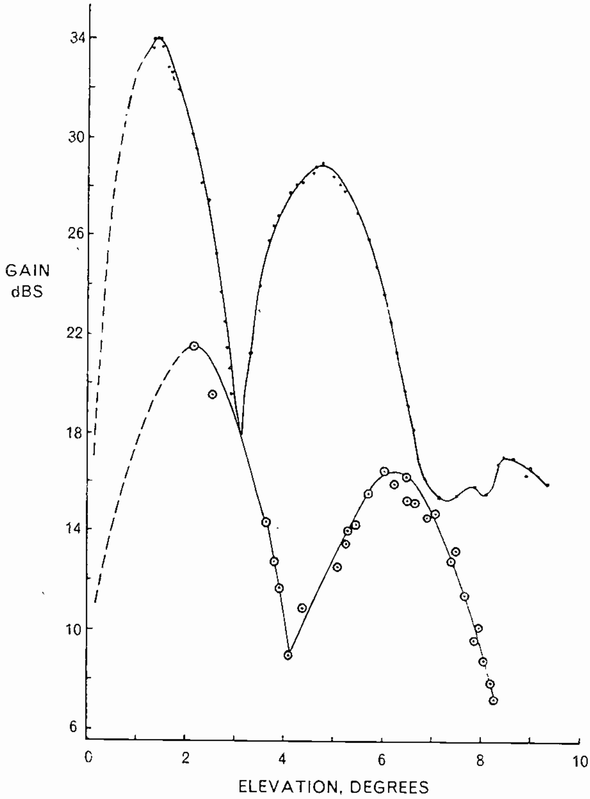


*Fig. 5. Vertical polar diagrams of two 600 Mc/s radar aerials*

his was of quite manageable size but gave a good sun signal. In practice, easurements were made on the large array, then on the gain horn, then gain on the large array, all in one day. The large array measurements gain agreed well with those of Fig. 4, although the measurements were ome months later, and a figure for the maximum gain of the large array esulted. It is thought that this result could not be achieved by other eans.

## ome Possible Sources of Error

orrections to vertical polar diagrams and gain measurements will be equired, especially at small angles of elevation, to take account of tmospheric attenuation and refraction, which is greater at radio wavengths than for light(10). The finite size of the sun's disc will mask ground eflection effects if the lobes of the ground reflection pattern are smaller han 1/2°, as they were, for example, in the case of Fig. 4. Moreover, if he horizontal beam width is comparable with 1/2°, the aerial will receive ss signal than from a point source giving the same flux density as the sun so that a small correction to gain measurements may be required, since the comparison aerial, being smaller, will see the sun as a point source.

## The Advantages of the Solar Noise Methods

The difficulties of other methods of measuring the VPD of a large radar array have already been mentioned; the solar noise method alone gives the required result, and this without any apparatus external to the radar. There is no difficulty, as there is on an aerial test site, in keeping transmitter and receiver in tune. There are no problems of squint as there are when measuring sections of the array on a test site. The frequency characteristics of the aerial array may be explored relatively quickly, and, finally, the sun provides almost the only practical source for gain comparison measurements.

## Other Radio Sources

It is natural to inquire whether any others of the thousands of radio sources so far catalogued may not be easily detectable with radar aerials. The advantages would be considerable, since the other sources are generally

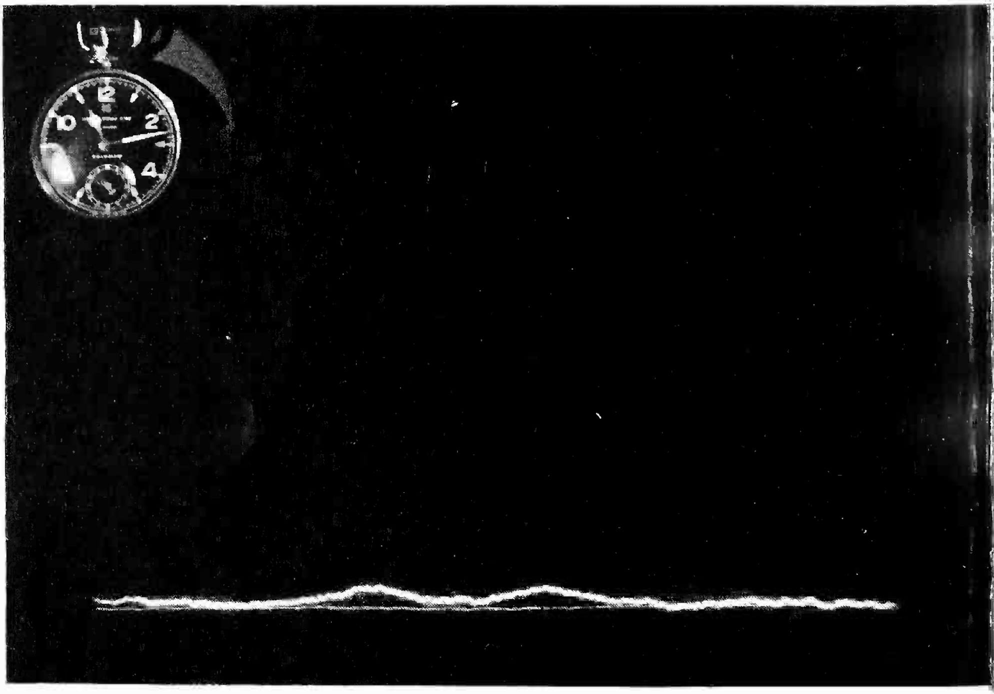


*Fig. 6. Signals received from the radio source Cygnus A as the aerial beam sweeps through its azimuth. 11.13 B.S.T. 26th August 1958*

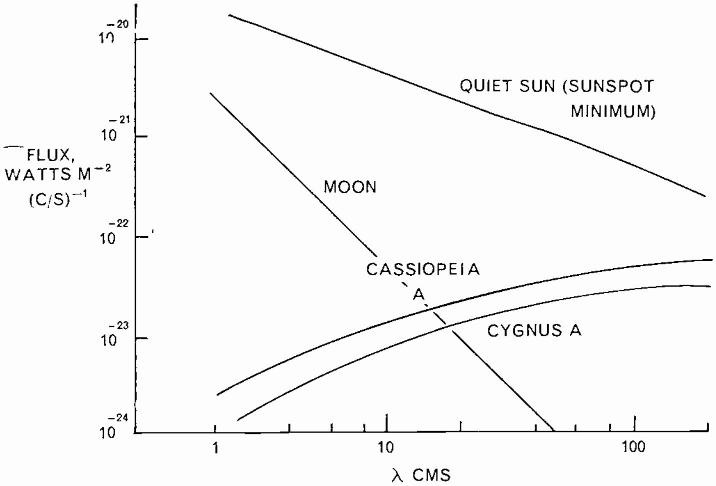


*Fig. 7. Spectra of the more powerful radio sources*

maller in angular size and more constant in radio power output, even if he absolute value of this output is not known to better than 10 or 15%. lowever, it turns out that only the most powerful sources can be detected y any aerial of reasonable size and a straight receiver at microwave equencies. Since the strongest of all sources, Cassiopeia A (RA 23h 1m 12s, Dec. 58° 32′) never comes below 20° in elevation in this latitude 51·5° N), it is not detectable by radar aerials having their maximum gain t low angles. However, the second most powerful source, Cygnus A RA 14h 57m 45s, Dec. 40° 35′) has a minimum elevation of less than 3°, ven allowing for refraction, and may be detectable on the largest aerials. 'his source is among the most interesting in the sky. It was the first iscrete source detected and appears to consist of two spiral galaxies in ollision and to emit as much power in its radio as in its near-visible pectrum. Its strength as a radio source is such that it could still be etected at 30 times its estimated distance of 3 × $10^8$ light years, although would then be out of reach of the largest optical telescope. Fig. 6 shows photograph of the response from this source, whose spectrum, together ith that of the quiet Sun, Moon and Cassiopeia A, is shown in Fig. 7. 'he next most powerful sources are considerably weaker than those lready mentioned and will not be detectable by straight methods on any ut exceptionally large radar aerials until very low noise receivers become vailable.

The Moon is an interesting special case. Its microwave temperature ppears to be constant with frequency at about 200°, and does not vary s much as would be expected with lunar phase. It should be easily etectable with a straight system at wavelengths of 10 cms or less.

## Conclusion

An account of solar radiation at microwave wavelengths and of a simple experimental method for its detection and use in the measurement of the vertical polar diagrams and gain of large aerials such as those used for radars, has been given. Typical results are shown and attention is drawn to other radio sources which may be detectable.

## Acknowledgements

The author wishes to thank Dr. E. Eastwood, Chief of Research, Marconi's Wireless Telegraph Co. Ltd., for permission to publish this paper.

Very many of his colleagues contributed to the success of the experiments, but especial thanks are due to Miss A. P. Darwent and Messrs. G. Downie, E. Bowan and D. Thorn.

## References

1 J. L. Pawsey and R. N. Bracewell: *Radio Astronomy*, O.U.P., 1955. R. Hanbury Brown and A. C. B. Lovell: *The Exploration of Space by Radio*, Chapman & Hall London, 1957.
2 Taken from monthly reports *Solar Geophysical Data* issued by Central Radio Propagatio Laboratory, U.S. National Bureau of Standards.
3 J. S. Hey and V. A. Hughes: "A Method of Calibrating Centimetric Radiometers usin Standard Noise Sources." *Proc. I.R.E.*, 46. 119. Jan. 1958.
W. J. Medd and A. E. Covington: " Discussion of 10·7 cm Solar Radio Flux Measurements and an Estimation of the Accuracy of Observations." *ibid.* p. 112.
4 J. A. Giordmaine, L. E. Alsop, C. H. Mayer and C. H. Townes: "A Maser Amplifie for Radio Astronomy at X-Band." *Proc. I.R.E.*, 47, 1063, June 1959.
5 R. H. Dicke: " The Measurements of Thermal Radiation at Microwave Frequencies" *Rev. Sci. Instr.*, 17, 268, July 1946.
6 F. H. Drake and H. I. Ewen: "A Broadband Microwave Source Comparison Radiometer for Advanced Research in Radio Astronomy." *Proc. I.R.E.*, 46, 53, Jan. 1958
7 M. Ryle and D. D. Vonberg: *Proc. Roy. Soc.*, A.193, 98, 1948.
8 M. Ryle: " Radio Astronomy." *Reports on Progress in Physics*, 13, 184, 1950.
9 E. H. Braun: " Gain of Electromagnetic Horns." *Proc. I.R.E.* 41, 109, Jan. 1953.
10 Pawsey and Bracewell, *loc. cit;* for refraction, see Fig. 146, p. 344, and for attenuatio Fig. 145, p. 341.

# AERIAL CALIBRATION BY SOLAR NOISE USING POLAR DISPLAY

By M. H. CUFFLIN, B.Sc, (Hons)

*uring the summer of the International Geophysical Year 1957, some xperimental investigations were made at Bedell's End, near Chelmsford, ith two objects in view. One was the possibility of using the radio noise of the un as a suitably remote source for plotting the vertical polar diagram of an erial. The other was an attempt to repeat an observation made by Dr. E. astwood* at the radar station at Trimley in Suffolk in 1955, of a suspected flection from the moon during a very intense eruption of solar noise. This, was felt, would be an interesting contribution by Marconi's Wireless elegraph Company to the world-wide work of the I.G.Y.*

*The usefulness of the first aim was successfully demonstrated and has since en applied in the Company's research work. This article is largely concerned ith the experimental equipment used and the reasons for particular circuit rangements, with a description of some interesting records.*

*The second object of the work was not achieved. Normally, the level of the lar radiation was insufficient, but on the one occasion when the sun was in an hanced state of activity the moon was not in a position suitable for servation.*

## nitial Experiments

ollowing development and engineering work on a VHF radar the Com- any was left in possession of a metric radar aerial mount with driving echanism, and a moving coil type console with PPI display. On the rial frame were mounted, back-to-back, two experimental aerial arrays, ne operating on 202·5 Mc/s, the other on 250 Mc/s.† The 202·5 Mc/s rray comprised twelve horizontal dipoles arranged end to end in a single ack approximately λ/8 in front of a wire mesh reflector. This gave fectively twelve maximum lobes in elevation, while the main horizontal eamwidth was 4·5°. The 250 Mc/s aerial contained four stacks, each sixteen horizontal dipoles, fixed vertically one above the other, also 8 in front of a wire mesh reflector. This gave effectively only three aximum lobes with a main beamwidth of 3·5° azimuth. For comparison e theoretical lobes are shown in the table overleaf.

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Chief of Research, Marconi's Wireless Telegraph Company.

Refer to Dr. Eastwood's article " Aerial Investigations Using Natural Noise Sources," g. 4, page 9.

| Aerial Lobe No. | 1 | 2 | 3 | 4 | 5 | 6 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 202·5 Mc/s | 2·43° | 7·3° | 12·3° | 17·3° | 22·5° | 27·9° | 33·6° | 39·7° | 45° | 54° | 64° |
| 250 Mc/s | 2·3° | 6·9° | 11·5° | (16·3°) | — | — | — | — | — | — | — |

The 202·5 Mc/s aerial offered a wide angle of reception in elevation, whil the 250 Mc/s aerial was " low-looking." It was obvious that the latte would only be effective during a period from one-and-a-half to two hour after sunrise or before sunset.

To make convenient use of the two aerials a head amplifier and mixe for each aerial were installed in the cabin on the aerial column, the outpu of each being at the IF, 50 Mc/s. A remotely controlled relay switc permitted either output to be presented to the main IF amplifier as require

In the early observations, a normal PPI form of presentation was use The noise from the sun appeared as a narrow band, brighter than th general receiver noise, as shown at A in Fig. 1. Unfortunately, as the su changed its position in elevation and passed into the aerial minima, became increasingly difficult to discriminate between receiver and sol noise and the precise observation of the minima was impossible. Th elevation of the sun was obtained by recording the time of a particul

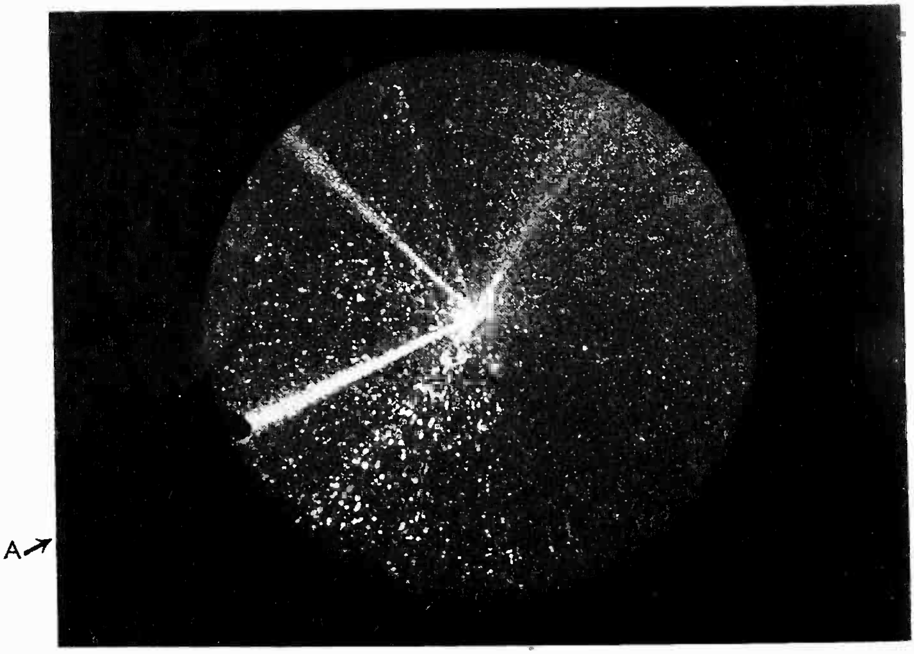

*Fig. 1. PPI Record*

ent and calculating the angle with the aid of nautical tables. This was ore accurate and reliable than direct measurement with the aid of a eodolite, which needed some skill and an extra person to make observa-ons, and was, of course, useless on cloudy days.

## ntegrating display

he poor resolution of the noise minima on the PPI display led to the troduction of a modified display which overcame this handicap and rovided the beginnings of a useful instrument with other possible pplications.

The modification abolished the normal PPI with its constantly repeated dial time base. Instead a radial scan was developed whose length was lated to the received signal strength. As the aerial rotated, followed by e rotating deflector coil assembly, a bright polar pattern was drawn n the cathode ray tube screen, consisting of a large number of straight dial lines of varying lengths emanating from the centre. It was now very sy to see when received signals faded to a minimum. Even signals well low receiver noise caused a visible increase in the scan radius.

If two signals, $n_1$ representing receiver background noise, and $n_2$ solar ise, are added, the resultant is

$$N = \sqrt{n_1^2 + n_2^2}$$

, then, the scan radius were proportional to the signal, $R_1 = k.\ n_1$ for rmal receiver noise and $R_2 = k.\sqrt{n_1^2 + n_2^2}$ for added solar noise.

or $n_2 = n_1$, $R_2 = R_0\sqrt{2}$ i.e., 41% increase in radius.

or $n_2 = n_1/4$ i.e., 12 dBs below receiver noise.

$$R_2 = R_0\sqrt{1 + \frac{1}{16}}$$

$\doteqdot R_0\ (1{\cdot}03)$ i.e., 3 % increase in radius.

his illustrates the enhanced sensitivity of observations of the minima.

This signal integrator was achieved with a few simple modifications. he schematic diagram of the whole system is shown in Fig. 2. The grid sistance, R, of the Miller integrator was connected to the rectified gnals from a diode following the video amplifier. No signal brightening as applied to the grid of the cathode ray tube although a blanking pulse moved the flyback trace. The integrating period was approximately 800 microseconds at a repetition period of 4,000 microseconds, i.e., at 50 c/s. During the integration period the rate of change of the integrator tput varied instantaneously with a change of input signal, although the nal excursion, and hence length of scan, depended on the average signal

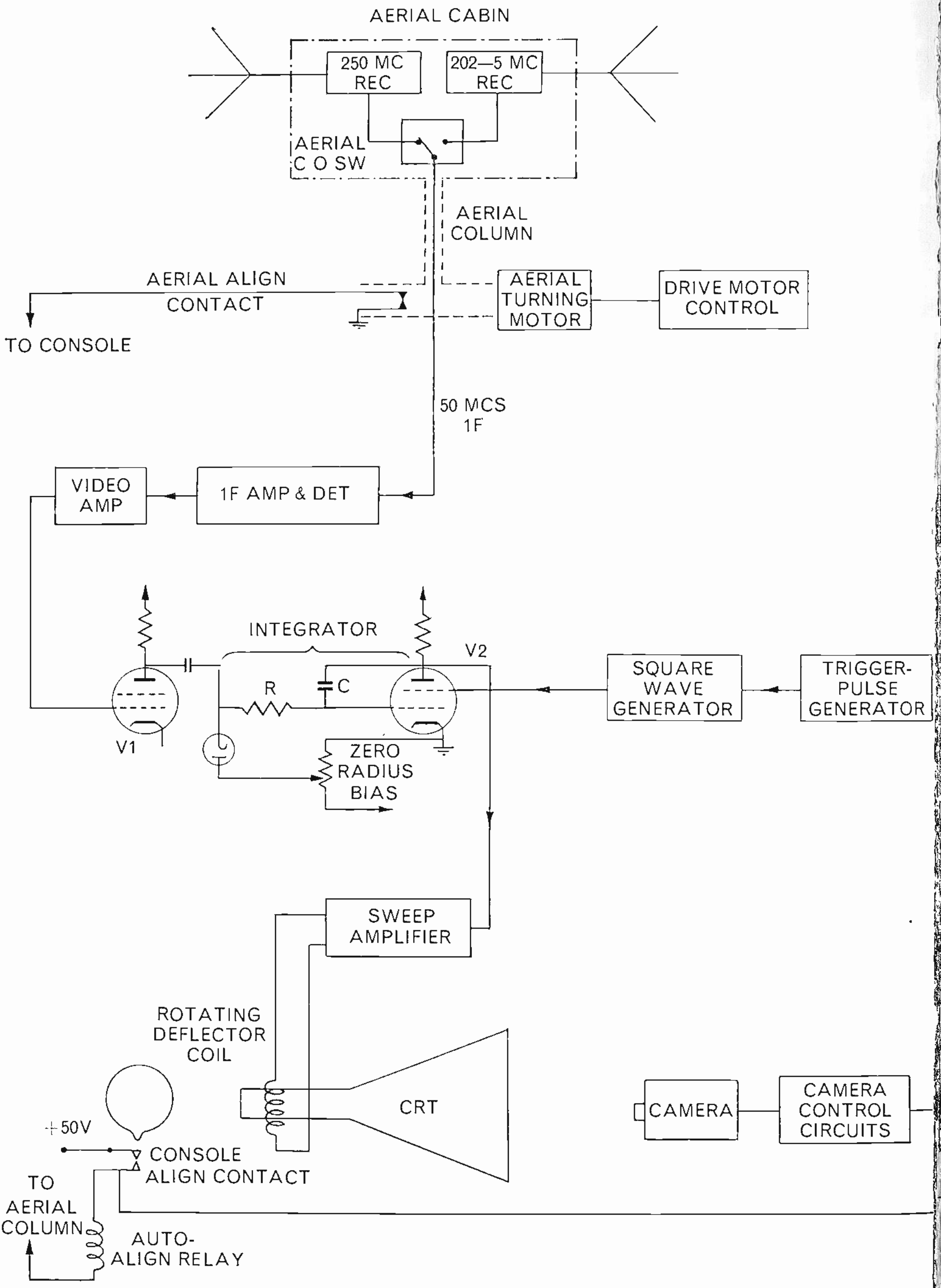

*Fig. 2. Block diagram of integrating display*

uring the period. It can, therefore, reasonably be said that the response requency of the system was limited to 250 c/s. There was, therefore, no ractical delay between a signal arriving on the aerial and its recording on he cathode ray tube screen.

A minor defect of the original Miller integrator was the initial nstantaneous potential drop at the anode, caused by the excursion of rid potential from zero bias to near cutoff potential at the start of the ontrolling square-wave. This caused a minimum radius of scan when no ignals were applied to the integrator. It was overcome as shown in Fig. 2 y a small negative bias, almost to cutoff value, applied via the rectifying iode.

Although no precise measurement was made to obtain the linearity of nput v. output, a simple test with a signal generator showed approximate nearity over a 10:1 input range, with a change of radius of the scan from inches to 0·5 inch. It was realized that several factors could influence he performance including the linearity of the various stages of the receiver, he video rectifier and deflection amplifier. It would be possible to reduce he overall number of stages by feeding the output of the second detector irectly to the integrator, avoiding demodulation and video amplification ith their attendant distortions, but it was inconvenient in this experiment ue to the distance between various sections of equipment.

It was found convenient, to obtain a paint of reasonable radius for the olar noise, so to adjust the receiver gain that the background noise enerated a disc about half the maximum diameter. For stronger signals he noise radius could be reduced.

## utomatic Camera Control

he circuit of the camera is shown in Fig. 3. The “ prime mover ” used in ontrolling the camera was the auto-align contact in the console. When the erial and moving coil drive were running in correct alignment, the auto-lign contact closed over an arc of 5° as the aerial “ aspect ” passed hrough the North bearing. The contacts controlled a DC supply of 50 volts. he moment of initial contact was used for camera timing. However, in ttempting to use this initial closure to trigger an all-electronic circuit it as found that random noise and hum pick-up due to long auto-align ontrol leads, and occasional contact bounce, resulted in hopelessly erratic iggering. It was found more reliable to use relays, to isolate the auto-lign circuit from the trigger circuit, and to derive timed transfer pulses operate a Decatron Switch Valve GS10C, as a decade counter.

In the circuit, relays A/2 and B/1, with their associated circuits, were connected that they operated sequentially when the 50V supply was pplied to A/2 via the 2 μF condenser on the closing of the auto-align ontact. This input, being of low impedance and having a long time

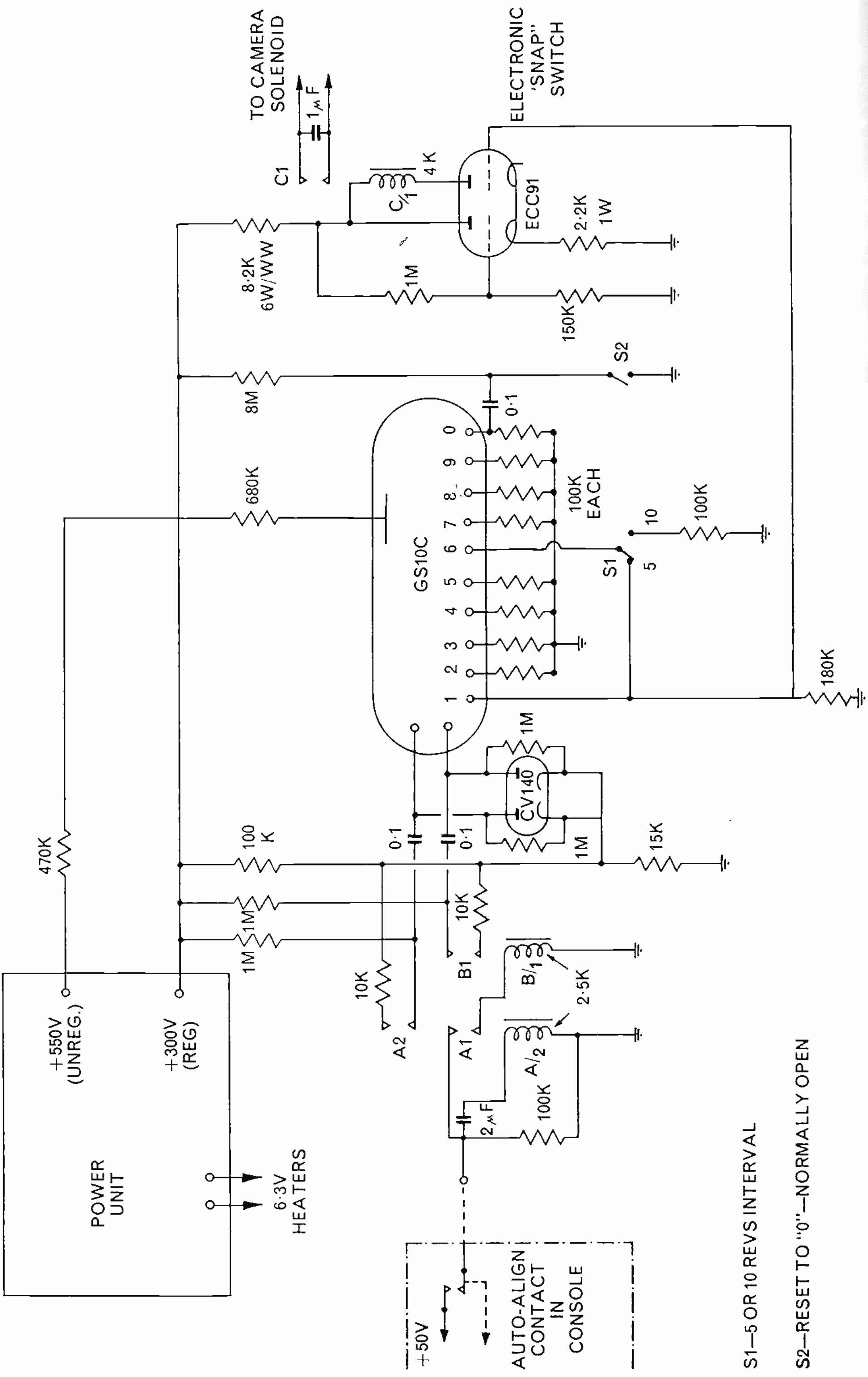

*Fig. 3. Camera Control Circuit*

onstant, smoothed any irregularities due to contact bounce and ignored um and random noise. Charges, accumulated during the " waiting " eriod on the 0·1 μF condensers, were discharged by contacts A2 and B1 nd caused transient negative pulses in sequence to appear on the ecatron guide electrodes. The glow discharge thus transferred from one athode to the next at each revolution of the aerial and remained on that athode for one revolution. When on cathodes one or six, the camera would e switched on.

The same principle of a stored charge was used for " zero re-set." losing of push button switch S2 earthed the " live " side of a 0·1 μF ondenser (charged via the 8MΩ resister). This applied a very large egative transient to cathode "O", which thereby seized the glow discharge nd set the counter to zero, awaiting the next transient of the auto-align am. This was very convenient when it was desired to start a recording at given time or to record a series of phenomena on each rotation. Normally he counter would permit the camera to operate for only one rotation in ive or ten according to the position of switch S1. This was to reduce onsumption of recording film, when slow moving events, such as the ransit of the sun, were being recorded. This automatic camera control vould permit a continuous watch up to ten or twelve hours with little nore than supervisory attention.

## ypical Records

A number of records were taken including extended periods of up to two ours before sunset. It was possible to determine minima, i.e. the passage f the sun through the minima in the vertical polar diagram of the aerial, o an accuracy of ± 1 minute of time. This corresponded to a vertical ngle accuracy of ± 7·5′ depending on the rate of climb or fall of the un for the time of day. In any such measurement the sharpness of the bserved minimum must depend on the relative width of the actual ninimum compared with the effective angle subtended by the sun. The ptical diameter of the sun is about 32′ of arc, varying slightly with the eason. From the point of view of the radio aerial the diameter is less than he optical diameter, particularly when a burst of energy arises occasionally from a small area such as a sun spot. These bursts are relatively uncommon, however, and any use of the sun for aerial calibration should llow for a number of measurements to obtain an average. In general, the nore lobes that exist in an aerial diagram, the sharper, in terms of dBs/degree are the minima. The sun will therefore straddle the minima, which will apparently be less obvious. It will be equivalent in effect to the passage of an opaque shutter over the surface of the sun. If the width of the shutter is less than the solar diameter, some radiation will always pass, and there will never be absolute darkness.

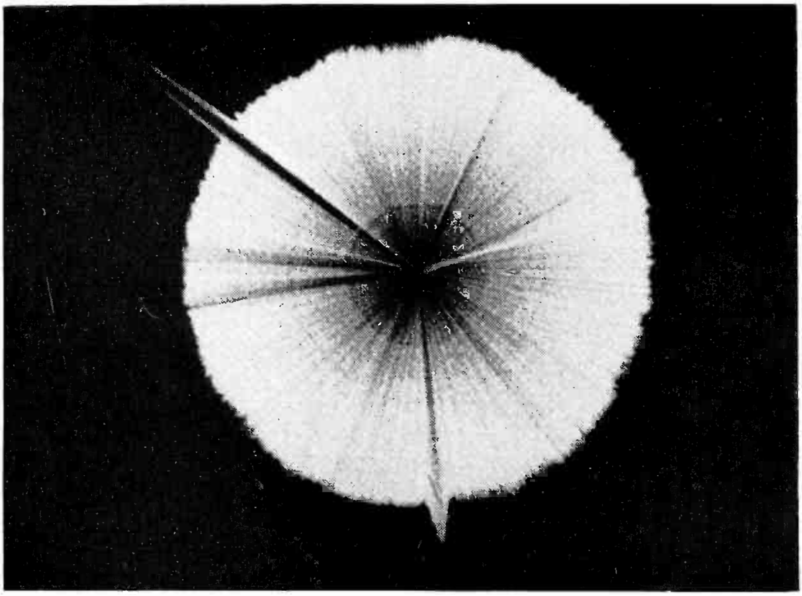

*Fig. 4. Record of Quiet Sun, 250 Mc/s*

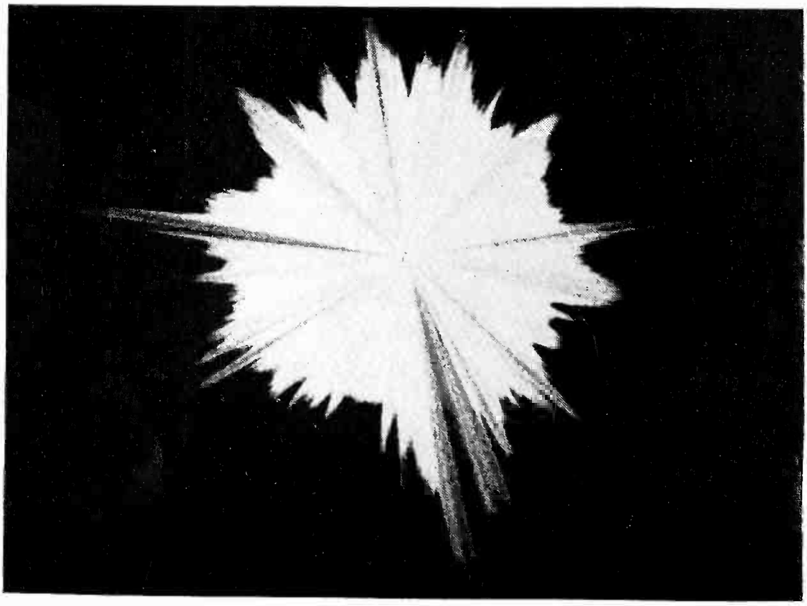

*Fig. 5. Record of Radar Jamming 202·5 Mc/s*

Typical extracts from records are shown in Fig. 4 to Fig. 8. Fig. 4 shows a quiet background of receiver noise with a sharp peak due to solar noise. The small peak was from a weak CW transmitter on 250 Mc/s.

Fig. 5 shows severe jamming from radars on 202·5 Mc/s. The peak

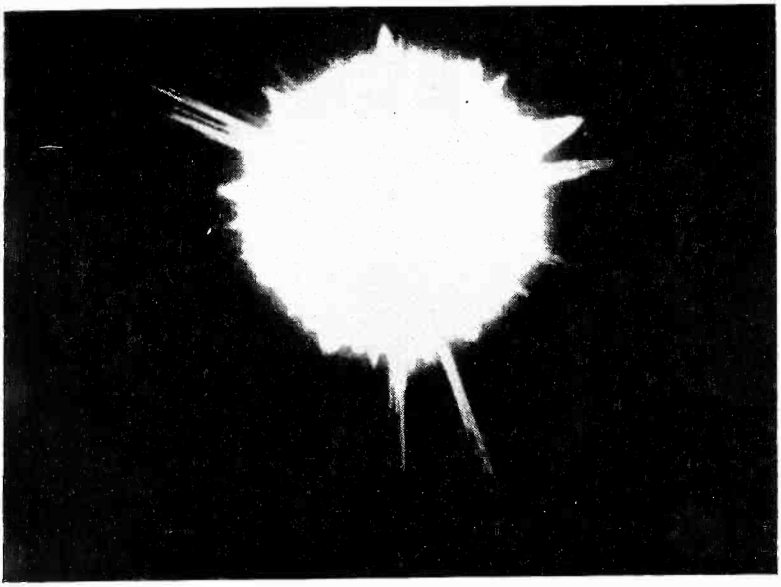

*Fig. 6. Record during thunderstorm*

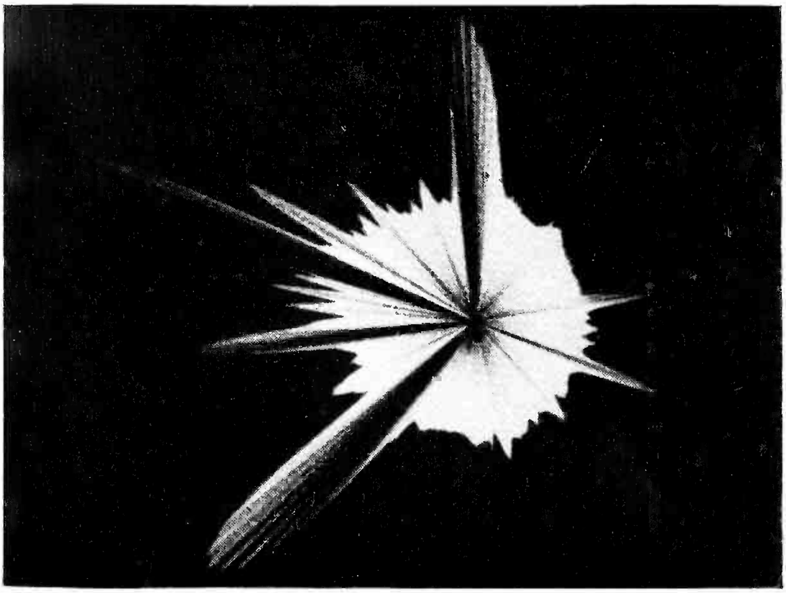

*Fig. 7. Record of " Polar diagram " due to CW source on 202·5 Mc/s*

ergy is such that they were received on all side lobes of the receiving rial. Four or five radars were involved.

Fig. 6 was recorded during a summer thunderstorm. Although the ntral area was marred by halation due to over-exposure of the film, very sharp pulses were recorded due to lightning flashes. Some idea of the duration of these flashes can be obtained from the aerial speed, which was about 3 r.p.m. Flashes occurred every few seconds. The angular position of the peaks did not correspond to the bearing of the flashes; their power was sufficient to break through, whatever direction the main aerial beam was pointing. It was also noticed that the general noise increased during the onset of the storm. This may have been caused by precipitation charges from the rain striking the aerial.

Fig. 7 is a record of a CW transmission of considerable power, with the receiver gain reduced. A polar diagram of the receiving aerial was thus obtained.

Fig. 8 is a record of a greatly increased solar noise radiation, with several small interfering signals from radar sources.

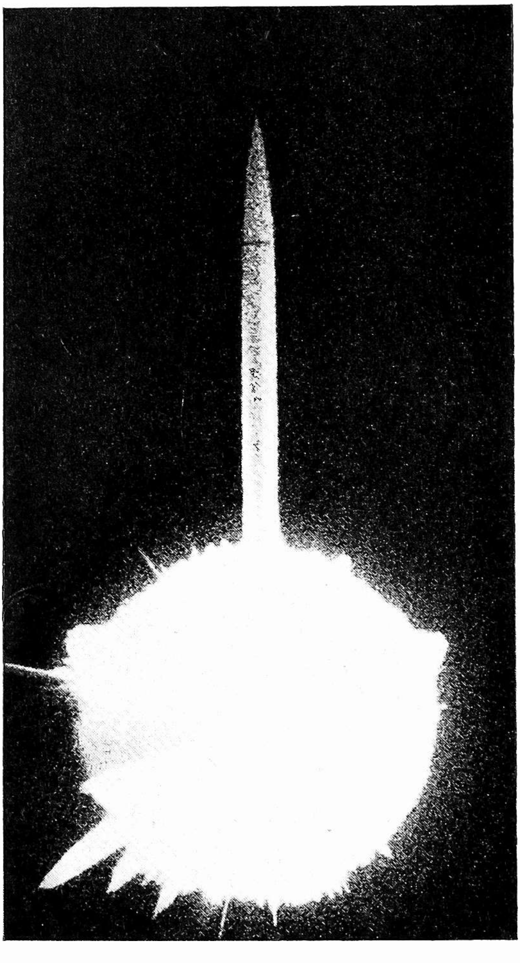

*Fig. 8. Record of abnormal solar noise, 202·5 Mc/s*

## xample of Aerial Check Using Minima

bservations made with the 202·5 Mc/s aerial gave maxima and minima follows:

Min. at elevation 36·8° (sine = 0·6000)
Max. ,, ,, 39·7° (sine = 0·6388)
Min. ,, ,, 42·5° (sine = 0·6756)
Max. ,, ,, 45·7° (sine = 0·7157)
Min. ,, ,, 50·5° (sine = 0·7710)

It was uncertain which order of maxima and minima were recorded ut these were deduced from the equation for the elevation of minima, e.

$$\text{Sine of elevation angle} = \frac{n\lambda}{2h}$$

here $\lambda$ = wavelength, $h$ = effective height of aerial, $n$ = order of inimum, taking the minimum at zero elevation as $n = 0$.

r the minimum at 36·8° $\frac{n\lambda}{2h} = 0{\cdot}6000$

d for the minimum at 50·5°

$$\frac{(n+2)\lambda}{2h} = 0{\cdot}7710$$

us,

$$\frac{n}{0{\cdot}600} = \frac{n+2}{0{\cdot}771}$$

ving $n = 7$ for the minimum at 36·8°.

t 202·5 Mc/s, $\lambda = 1{\cdot}48$ metres. Substituting these values in the equation,

$$0{\cdot}600 = \frac{7 \times 1{\cdot}48}{2h}$$

us,

$$h = 8{\cdot}65 \text{ m.}$$
$$= 28{\cdot}4 \text{ feet.}$$

his corresponded well with the known height to the centre of the aerial f 28·5 feet, and indicated the accuracy obtainable. It also indicated that s far as the flat farmland site of Bedell's End was concerned, it was orrect to assume the "reflecting plane" as being the actual surface of e ground.

## onclusion

he experiments succeeded in proving that the noise radiation from the n can be used to plot the vertical polar diagram of an aerial. The work was not carried to the extent of evolving a method of finding the relativ gain in the various lobes. There is no doubt that if the input signal had been constantly compared, by a " chopper " method, with a local signa source, giving standard levels as marker rings, the gain could be measure accurately over extended periods. This method could be easily adapted t become a means of plotting the polar diagram of any aerial in any plane using a reasonably distant CW source.

## Acknowledgements

The author expresses his appreciation to his colleagues, Mr. R. F. O'Neil and Mr. A. Smith, for their assistance in the practical work and to Dr D. H. Shinn for supplying data on the movements of the sun and moon

# BOOK REVIEWS

RADIO ENGINEERING HANDBOOK. *Edited by Keith Henney*
McGraw-Hill Book Co. Ltd. Price £9 14s.

No fewer than thirty-four specialists combined under the editorship of Keith Henney to produce this, the fifth edition of a handbook which made its first appearance in 1933. In the subsequent twenty-six years, radio engineering has developed to such an extent that scarcely any aspect of our lives remains unaffected by it; it is, therefore, not perhaps to be wondered at that even an 1,800 page book such as this, comprising upwards of a million words (it would take three days and nights to read it at an average rate of 250 words per minute), leaves large areas of detail unexplored. Neither is it surprising that the quality varies substantially from chapter to chapter, for the task of editing such a work can be nothing less than formidable.

Nevertheless, the prospective buyer is entitled to expect a work of more than average merit for the £9 14s. at which it is priced, and it is with this consideration that this review must be concerned.

The list of contents shows that, after an introductory chapter entitled "Basis of Radio-communication Engineering," in which is presented a sketch of the fundamental principles involved, the book can be divided into four main sections covering broadly: Circuit Elements and their Properies (eleven chapters), Measurements (two chapters), Circuits, including aerials (si chapters), and Systems (eight chapters Each chapter is the work of a differen author (or authors); this is all too obviou as what little overall editing has bee attempted has resulted in considerable ove lapping of subject matter and no obviou uniformity of treatment. Indeed the Handbook conveys an impression of haphazar assembly, apart from the broad patter indicated by the chapter headings. Thi haphazardness can be illustrated by a example taken from Chapters 2, 3, and which deal, respectively, with Resistanc Inductance, and Capacitance. It might b supposed that with these at his elbow designer would have all the fundament information required to design resisto inductors, and capacitors to meet his speci needs. Yet, in fact, data on wires an resistance materials are lacking fro Chapter 2, which deals at length chiefl with many aspects of proprietary types resistor (that this may be indicative of th adequacy of the proprietary range for an conceivable application is, surely, beside th point).

The chapters on Inductance and Capacitance adopt a more rational approach an are generally satisfactory.

Here, then, we see some of the problem

h which the editor of a work such as this aced — how free a hand is he to give his ociates, to what extent should he impress own personality upon the book; what uld he include in detail, what in broad ns; what subjects should be reserved for ibliography; how far should he strive for formity of presentation, how may he id an impression of incoherence? The cess or otherwise of the work depends on making the right compromises, just as any branch of creative endeavour.

n the opinion of the reviewer this work, t in conception and in sheer weight of rds as it is, fails through editorial indecision. It is a book which will, very properly, find its way into the reference sections of libraries, and it will on occasion provide the seeker with an adequate survey of some aspect of radio engineering; more often it may suggest references for further reading from its relatively meagre bibliography; seldom is detailed design information of the kind one might reasonably expect in so highly priced a book to be found.

In short, a book priced at £9 14s. must be of exceptional quality if it is to justify its publication; Mr. Henney's work fails by this standard, notwithstanding the galaxy of the talent he has had at his disposal.

## IDE TECHNIQUE DE L'ELECTRONIQUE PROFESSIONNELLE

l Edition 1959. *General Editor: Robert Domenach*

ence Publeditec-Domenach, Paris. 2 Vols. 5,500 Fr.

s not enough to know how to make and things well, but for continued success it essential to advertise that knowledge. is is the theme of the *Guide Technique de lectronique Professionnelle*, neatly sumrised in a preface by: "*Savoir faire, bien re . . . il faut aussi: faire savoir.*"

ts purpose is to put before the new ropean Common Market the achievents and potentialities of the French ctronics Industry, in all its branches.

The two volumes of the Guide are to some ent usable independently. The main ume contains the presentation of the ievements and the vast amount of vertising. These sections are attractively strated and catalogued in colour and are eresting, even fascinating. The smaller lume contains the classified reference ts and business directories, and a few ple checks showed that a user could find answer to his enquiry in a few seconds. is avoids a long search through 500 pages distracting advertising, a feature which ll be of value to many, whether business ecutive, sales and purchasing departnts, or design and engineering staff. This ried use, however, could result in the two lumes becoming separated, which would ate inconvenience. It is a pity, also that ch excellent material is contained in ther cheap and easily damaged covers.

The sections dealing with French achievents, and the classified subject lists and directories are in French, English, German and Italian. Advertising is in French and English. The Guide thus becomes an illustrated technical glossary in four languages, which many users may find of value, apart from its main function. The sections mentioned are, for the most part, well, if freely, translated into English, but unfortunately, some advertisers have very poor translations, a few making nonsense.

There are rather too many English printing errors, some of which are amusing, as, for example, in the second preface, where "production drive" is printed as "production dive."

In general, it is easier to read those catalogue sections where the English text is separated from the French in blocks of smaller type, rather than those which are interleaved line by line.

It is a little surprising to find much American equipment advertised under a guide to French Electronics, since a sales agency cannot be an industry in the sense claimed by the Guide. However, the influence of the U.S.A. is seen in the classified lists where "valves" refers entirely to mechanical types. Radio valves must be sought under "tubes" and tubes appear under "piping."

The editors have chosen to adopt the American usage of words; a note, in parentheses, where this occurs might be of use for English readers.

## PRINCIPLES AND PRACTICE OF RADAR (SIXTH EDITION)

*by H. E. Penrose and R. S. H. Boulding.* George Newnes Ltd. Price 50s.

The authors have attempted, like many others, to cover a very wide subject in one book without the use of mathematics, to such an extent that this book must be classed as one belonging to the Popular Press Category.

There may have been justification in the early 1920 period to develop the theory of transmission lines from a resistance ladder network but, today, there can be little justification for such an approach in an appendix to a book such as this, particularly when it is followed by an appendix on waveguides.

Although in many places the authors state that the reader is assumed to be familiar with the more usual radio circuits they find it necessary to run through basic principles but in such a skimpy manner as to be of little or no value to the reader.

Some 280 pages out of a total of 800 are given over to description of actual equipment manufactured by some six British manufacturers. This description is clear and quite detailed but it is puzzling to find that circular polarization and MTI are dealt with in this section rather than under the "Principles " section.

The preface states that " later developments such as lenses, slot aerials, slot arrays, and the Cosecant Squared aerial have been added " but not more than one page is given to any of the above subjects. Fortunately, they have all been very fully covered in the literature since the war.

The phraseology is in many instances difficult to follow. For example when the student has mastered the meaning of the title of Chapter IX " Rectangular pulses having a definite time duration and the development of high voltage high power time control pulses at low and high level " he will then have to struggle through several explanations followed by " In other words " or " That is to say . . .".

From reading the book it is impossible to obtain a clear understanding of impedance matching. If the simple calculations on matching a cathode follower into a coaxial cable, page 134, had been taken a little further and the useful power into the cable load calculated it would be realized that the matching exercise was a very effective method of putting energy where it is no wanted. The authors do not make it clea why matching is desirable in this case. The last paragraph on page 140 is equally misleading particularly when it is appreciate that the most common type of high powe pulse modulator, i.e., the artificial line and thyratron modulator, has very poor regulation.

When the authors state that the alternative to a hard valve modulator, which they state has an upper limit of 27 kV operating potential, is a spark gap they neglect completely high power modulator developmen during the last ten years. To brush aside th thyratron in one line in Chapter IX and hal a page on page 330 is doing the brilliant wor of many physicists a gross injustice. At th present day the rotary or stationary spar gap is probably only used in isolated case for laboratory test purposes, and it would b next to impossible to find one in a piece o service equipment.

The operating cycles of a number o multivibrator circuits are clearly dealt wit in Chapter X but a fully worked out exampl would have been useful.

Although over fifty pages are given t Time Base Circuits and Display Units, n reference is made to Fixed Coil Display and the many additional facilities that ca follow.

Certain errors exist in the illustrations For example the dots and crosses in Fig. 1 (4) indicating the magnetic field are incorrect and should be of a similar pattern t that indicated in Fig. 11 (*c*). The distance o the magnetic coupling loop from the en of the guide in Fig. 14 (*b*) should be $\lambda_2$ an not $\lambda_4$ as indicated.

From the general form of the waveguid illustrated in Fig. 18 (*a*) and 18 (*b*) one woul expect the equivalent dipole radiators t radiate with the same polarization. Th meaning to be conveyed by Fig. 18 (*a*) i not clear.

As an introduction to Chapter XXIX o " Typical Radar Installations " the author discuss two systems, intended to illustrat the application of general principles upo which radar systems are worked out. Th all important principle of the relationshi between peak transmitter power, puls gth, aerial gain, receiver noise factor and ctive target area, more commonly rred to as "The Radar Equation" ns to have been forgotten.

he above remarks criticize, in detail, e points which immediately strike the der. Summarizing, it may be said that Principles and Practices of Radar gives the reader an introduction to the elements of small radars.

It does not deal with the more complicated modern systems and particularly the highly complicated data handling side of modern radar.

## PERIMENTAL RADIO ENGINEERING *by E. T. A. Rapson*

Isaac Pitman and Sons Ltd. Price 12s. 6d.

experimental work that is so necessary any radio engineering course will be plemented very usefully by carrying out measurements and experiments out- d in this volume. As the author is head he Department of Electrical Engineering Southall Technical College, he is in a ourable position for planning such work. eneral, the experiments are graded, and udent is likely to find that a three or four r course at a technical college will take over the ground covered by the experi- ts roughly in the order given in the k. Starting with series and parallel uits and coupled circuits, measurements he static characteristics and dynamic stants of valves are described. A number xperiments in connection with ampli- , demodulators and oscillators are then n and also attenuators and filters. The l Section XIII contains seven experi- ts with cathode ray tubes, time bases applications.

he range of experiments is surprisingly e for a book of this size. This is possible ause of the abbreviated style of the hor and to the complete absence of ding. Nevertheless, each experiment is quately explained for the engineering dent; and component values are stated. st students will find the component values eat time saver, but the reviewer is not entirely in favour of helping an experimenter much in this respect: an intelligent student should know how to work out his own values.

Conclusions to be deduced from the experiments are outlined in thirty pages at the back of the book and these form a most valuable aid to the experimenter. So much so, indeed, that the omission of conclusions in respect of the experiments on transistors and the Foster Seeley frequency discriminator is unfortunate, especially as these are so important in the design of present types of radio receivers.

By and large, the experiments represent current practice but it is surprising to find some relating to the split anode magnetron. The Randall and Boot cavity magnetron superseded the split anode magnetron in 1941, and has been used almost exclusively in industry ever since. During revision, the opportunity should also have been taken to include measurements on the ratio detector which is used so extensively in F.M. receivers. The experiment on the amplitude discriminator is of little more than academic interest.

As a contribution to the literature for training radio engineers, this book is admirable. It is certainly worthy of a place in the library of every serious minded student.

## DIO CIRCUITS *by W. E. Miller, revised by E. A. W. Spreadbury*

e and Sons Ltd. Price 15s.

hough circuits are always interesting and n intriguing to an engineer, a beginner n finds them baffling, especially when sented with a diagram of a complete eiver. In the present Volume the authors sect the radio receiver and group to- her the various partial-circuits encountered in different types of receiver. The explanatory notes are written in an elementary style that will suit the tyro and which presuppose no technical knowledge on the reader's part.

*Radio Circuits* is far too ambitious a title for this little volume, for the authors have dealt only with broadcast receivers—communication receivers are not even mentioned. The broadcast receiver is broken down into such small divisions that there are thirty-eight chapters in the 170 pages. Indeed, the book tends to be disjointed because of this. For example, the aerial input circuits are covered by three chapters: "Aerial Input Circuits," " Tuned Input Circuits " and " Band Pass Coupling." The subject is nevertheless well treated at the level stated and the reader is introduced briefly, but logically, to the various stages starting at the " front end." Nine pages (three chapters) are devoted to A.G.C., and the different types of push-pull circuits are outlined. Negative feedback, tuning indicator devices and transistor receivers are each dealt with in a separate short chapter. The concluding section of thirteen pages is devoted to F.M. receivers.

It is a pity that the text was not cleared of "deadwood" during the revision. A chapt is included, for example, on " Early F. Circuits " which describes some frequenc changer circuits that have not been used i broadcast receivers since the early 'thirtie In another part of the book, several tunin indicators are described that have bee obsolescent since the middle 'thirties whe the cathode ray indicator made its bov The elementary reader will also be som what confused to be told on page thirty-or that additive mixers are not much used, an then to find that additive mixing is employe almost exclusively in transistor receive and F.M. receivers. In neither case, howeve is an explanation of the additive mixin process given.

These are minor criticisms of a usef volume on broadcast receiver circuits whi provides an introductory description of wide range of circuits used in present d models.

## PRINCIPLES OF FREQUENCY MODULATION

*by B. S. Camies.* Iliffe and Sons. Price 21s.

Frequency modulation is a subject that has received attention from a number of technical authors in recent years. This latest book on the subject is intended to appeal to engineers and amateurs in providing a survey of the art in its various applications.

The first three chapters form a theoretical explanation of frequency modulation and include one on frequency modulation in relation to interference. The reviewer considers this chapter to be the best in the book. Various types of interference are considered, including that due to the valves and circuits, and the treatment is comprehensive for a book of this size.

Frequency modulated generators are briefly described in Chapter 4, the various types including the frequency modulated quartz (FMQ) system. No acknowledgement is made to the Marconi Company as originators and patentees of the FMQ system nor is mention made of the extensive use by the BBC of transmitters based on this system. However, acknowledgement is given to Armstrong for his design of modulator. Reference might have been made to the serrasoid system which, although not in favour in this country, has been used in the United States.

FM receivers are dealt with in two chapters, one being devoted to FM detection. These provide a sound practic description of the FM receiver, and curre types of discriminators, e.g. the Foste Seeley and the ratio detector are ad quately dealt with. Some confusion likely to arise from the circuit shown page 93 which purports to illustrate t ratio detector arranged to provide AG The only difference between this circuit a the one given on the page facing it is th the polarity of the reservoir capacitor h been reversed. The diodes themselv should also, of course, have been reverse

The non-broadcast applications inclu the use of klystrons and the application FM to radar, including Doppler radar a FM radar. This is the least detailed part the book but should be regarded as introductory outline. The ten-page secti on radar, for example, starts at very fi principles of pulse radar and includes fo pages on Doppler radar and two on F radar.

The author's clear and direct st renders the text easy to follow, while t numerical examples included in the text w aid in the more elementary type of desi calculations. The author has succeeded his object and has produced a volume th will be a useful and practical guide to t less advanced engineer and student.

## NDAMENTALS OF RADIO TELEMETRY *by Marvin Tepper*

hn F. Rider Inc. Price $2.95

dio telemetry is an art that has come very ch to the fore in recent years, mainly ause of the spectacular advance in ided missile techniques and earth-bound ellites. Telemetry itself, however, is not ew art, having been the hunting ground inventors since before the turn of the tury. Probably the best known example radio telemetry is the radio sonde which been employed by the Air Ministry since middle 1930's. It is fitting that, in view the wide topical interest displayed, a ok should be produced. such as the one ler review, that purports to explain to layman some of the intricacies of the ject.

he author has attempted to present an rall picture of the radio telemetric art as lied to a large range of equipments. This very ambitious object for so small a k, especially bearing in mind the com- x nature of such aspects of telemetry data handling and digital techniques. wever, the volume is not intended to r more than the most elementary cription and this probably is the reason the inclusion of so many illustrations of cartoon type for the purpose of explain- even the most rudimentary features. In , a good half of the book consists of these strations.

The ground covered ranges from an introductory chapter on first principles. through multiplexing, data handling to the radio telemetry associated with missiles and satellites. A typical telemetric receiving station is described and a large chapter on recovering and recording the data. Page 93 virtually terminates the text but there follows a very useful bibliography (five pages) and also two appendices giving the United States standards on telemetry for guided missiles and magnetic recorders and reproducers.

It is not apparent to whom the book is directed, as the author does not seem to be able to make his mind up whether he is writing for a reader who is sufficiently knowledgeable to be able to assimilate, without explanation, the theoretical diagram (on page 22) of a six-valve transmitter for phase or frequency modulation; or for a tyro who cannot count and therefore has to be presented with a picture (page 43) of three specimen recording tapes showing respectively two, seven and fourteen recording tracks.

As an introduction to radio telemetry, this book may appeal to a layman who enjoys strip cartoons, but an engineer will seek his knowledge in more profound and balanced texts.

## EAR NETWORK ANALYSIS *by S. Seshu and N. Balabanian*

pman and Hall Ltd. Price £4 14s.

ing the last five years, a profusion of ks has appeared in the U.S.A., dealing electric network analysis and synthesis. t of these are edited versions of lecture es used in graduate courses at Universi- . The amount of material covered in m is roughly the same and this makes it difficult for a prospective student to ge their relative merits.

he authors of the present book are well wn in specialist circles from papers on work topology and frequency trans- mation respectively. They make a ified claim that their book attempts to oth out the transition between steady e or frequency and transient or time responses, as exemplified in the two classic works in these respective areas: Guillemin's *Communication Networks* and Gardner's and Barnes' *Transients in Linear Systems*. The text is written very lucidly; the flow of argument is easy to follow making it a valuable textbook. However, the diversity of aims causes the authors occasionally to stop the argument almost in mid-stream, in order to start with a new chapter. This is especially evident in the second half of the book where feedback, stability and filter theory are considered.

It is assumed that the reader is acquainted with the elements of the complex variable theory, Laplace transforms and elementary network analysis. The first four chapters deal with the fundamental concepts (loop and node systems of equations, elementary topology, etc.); the discussion on network elements is very illuminating—see, for example, discussion on relationship between perfect and ideal transformers.

The next two chapters deal with the steady state and the transient responses, containing among others an excellent treatment on steady state response to a general periodic excitation and on relationship between frequency and time responses. Chapter 7 concerns the analytic properties and representation of network functions. The so called Bode relations form the backbone of the argument. The authors follow here, very successfully, the treatment given by Guillemin in his *Mathematics of Circuit Analysis*. Complete and separate procedures are provided for calculation of network functions from given magnitude, angle or real part. It is a pity, however, that very little is said on how to obtain suitable initial functions, satisfying given requirements within some approximation. The potential analogue method, discussed here, has many obvious limitations, while nothing is said on the least square approximation, Tchebysheff's polynomials and other well-known mathematical tools.

The following two chapters deal with th elements of the quadripole (two-port ne works) theory, especially with variou matrix representations; the scatterin matrix is clearly represented. The Foster Reactance Theorem and Cauer's modific tion for RL and RC networks are al included here.

Chapter 10 contains elementary feedba and stability theory. The signal-flowgra technique is very ably explained. The discu sion on the stability criteria, however, cou have been profitably extended: the Hurwi continuous fraction test, when performe with limited accuracy, is often unreliable even misleading.

The last chapter, on image parameter an filter theory, is least satisfactory with scanty treatment of the determination image parameters. Also, no attempt is ma to correlate results of chapter 7 with a synthesis procedure. A short appendix giv elements of complex variable and Lapla transformation theory.

In spite of these criticisms this is a ve valuable contribution to the network liter ture and a convenient tutorial tool; origin and daring in treatment and scope, clear exposition, a stimulating stepping stone more complicated and difficult aspects of t theory.

## AN APPROACH TO ELECTRICAL SCIENCE

*by Henry G. Booker*. Published by McGraw-Hill Publishing Co. Ltd. Price 74s.

When the author of this book went to Cornell University he had already gained a wide reputation for his original outlook in presenting and applying electromagnetic theory. The appearance of this new treatise is therefore of particular interest to those who have to teach the fundamentals of electrical science, for the author has aimed at getting the best of all worlds by steering his way between the outlooks usually adopted by the electrical engineer, the physicist and the mathematician.

Following the physicist he begins with a discussion on electric charges and fields, but when he comes to consider magnetic fields he favours the viewpoint of the electrical engineer except that instead of working in terms of ampere turns per metre he shows that it is desirable to express the field in amperes per metre. Here he brings to bear his war-time experience of teaching rad to graduates in other subjects who had think of magnetic fields as they occur wave-guides and cavities rather than solenoids.

The treatment essentially relates electro-magnetic phenomena to the presen of electric charges which are static or motion. Forces on a charge which are result of its motion are said to be of magne origin and the concept of magnetic flux introduced by considering the movement charges in the space between the inner a outer conductors of a cylindrical tra mission line carrying a steady current. T idealized magnetic pole and the propert of magnets are then eventually deriv almost as a by-product instead of bei used to establish the existence and natu of magnetic fields.

The book claims to present a unified and f consistent description of electro-gnetism which can be used as a basis for ching the subject to a student who may have any knowledge of other approaches. such it is extremely well thought out and idly argued and it lends itself naturally the use of a single system of units.

t is difficult, however, to avoid the pression that the treatment is too facile, it dispenses very largely with the perimental basis of the historical ap-ach and replaces it with statements that made to appear almost self-evident. It is interesting speculation whether in princi- the knowledge of electromagnetic theory uld have been developed in the way this k implies.

Possibly the author could have done ter service to his cause by writing a rter book more especially for teachers to p them to re-think the knowledge of the ject that they already possess. As it is, book sets out to be not only a new proach but also a self-contained textbook roducing a great deal of standard proce-e. As such it is almost tedious in its ail; for instance it discusses network orems in basically the same way three es, first for capacitors, then for resistors finally for inductors, though in his preface the author seeks to justify this emphasis on the embracing nature of Kirchhoff's laws.

An attractive feature of the book is a set of summarizing exercises at the end of each chapter designed specifically to make the student prove to himself that he has understood the chapter, while at the end of the book are eighty pages of problems. The author has aimed at making the mathematics as simple as possible, and for this reason although he makes some use of vector algebra he stops short of using vector analysis.

He promises a sequel in which vector analysis will be used as a vehicle of thought in oscillation theory in contrast to the mere use of complex numbers as a tool for calculation. Here presumably he will deal in detail with wave theory which is only touched on in the present book. This further work will be eagerly awaited as it is certain to be even more original and stimulating. Meanwhile, although this "approach to electrical science" may not prove to be an ideal textbook, it will be an invaluable source of information to which many will continually refer, and not least those who are concerned with research and development work who need from time to time to refresh their ideas on the fundamentals of electromagnetism.

## VO-WAY RADIO *by Allan H. Lytel*

Graw-Hill, 1959. Price 74s.

is book deals in a practical way with ipment for radio telephone communica-n between road vehicles and fixed tions, using the frequency band 30—0 Mc/s. Such equipment is much less used Europe than in America, where over one d half million transmitters are in use. In S.A. this equipment may be repaired and usted only by licensed operators, the amination requirements for these licences ng outlined in the first chapter. The despread use of mobile radio in America ates a demand for qualified service gineers, and the non-mathematical ap-ach in the book is directed to those ders rather than to the design engineer.

The subject matter is almost entirely scriptive of existing commercial appara-s, with numerous illustrations. The intro-ctory chapter sketches mobile communi-ion systems and explains their purpose, with some advice about meeting the equipment regulations and licensing requirements. The basic differences between frequency- and amplitude-modulation are explained with numerous diagrams and almost without mathematics. The core of the book is composed of descriptions and explanations of frequency- and amplitude-modulated transmitters and receivers, with more attention to the former. The space devoted to single-sideband modulation is generous, considering that such methods have not yet been commercially introduced in the mobile service.

Most of the aerials used in the mobile service are described and illustrated, with informative polar diagrams showing their directional properties. The fundamental principles to be used when selecting an aerial are scarcely mentioned and half of the introductory material about aerials is inexplicably reserved for the final section of the chapter.

There is no indication how far selective calling of a single station in a network has been implemented in U.S. but examples of both tone and impulse systems are described in detail, specific equipments being singled out for treatment. It is surprising that resonant reeds are not mentioned. Vibrator and transistor oscillator power supplies are clearly explained without unnecessary detail.

Installation and servicing will constitute the main duties of the readers to whom the book is addressed. The important "do's and don'ts" of installation will be useful to the beginner, but it is doubtful whether the description of the tools and methods of the service engineer can compare with personal instruction and extensive bench experience.

The printing and illustrations are done in the excellent way which one expects in McGraw-Hill publications. It cannot be said that the material justifies this care. Some sections are a jumble of sentences, apparently derived from apparatus instruction books, with an ample sprinkling non-precise terms, which lead to diffic reading. Modulation and sidebands can introduced without mathematics with clea ly explained vector diagrams; in this bo the explanation is poor and some of t vector diagrams are so unorthodox as to incomprehensible. Of 277 well-printed illu trations, many are quite uninformati One photograph of mobile radio equ ment and one paragraph could convey the information of the seventeen phot graphs in Chapter 1, mostly showing hap truck drivers leaning, microphone in han from their driving cabs. How many reade will benefit from Figs. 9 —14, which sho how to knock the cover off one particu equipment?

A book intended for relatively no technical readers probably needs more ca in choice of material and presentation th one directed to highly skilled enginee Perhaps the ten years which the auth took to complete the book have someth to do with the confused impact which made on the reviewer.

### RADIO AND ELECTRONIC COMPONENTS Sir Isaac Pitman and Sons Ltd.

Vol. III Fixed Capacitors *by G. W. A. Dummer*. Price 45s.

Vol. IV Variable Capacitors and Trimmers *by G. W. A. Dummer*. Price 32s. 6d.

The first two volumes of this series, dealing with fixed and variable resistors, which were noticed in *Marconi Review* No. 123 have been followed by the two now under review. The same general arrangement has been followed. The first twenty or so pages of general information are common to both volumes, thus avoiding cross referencing. This is followed by a brief review of the types of component available, based in the case of Vol. III on dielectric material and, in Vol. IV on application and by methods of measurement of characteristics appropriate to each class.

Succeeding chapters deal with the vari types in detail, the last two covering possi faults and future developments respective

Both volumes include a very extens bibliography and a comprehensive co parison chart which facilitates selection a particular purpose. Service-type co ponents have been chosen as representat of the large number of types available this does not detract from the worth of th books which constitute a valuable source reference, not only to the components the selves, but to characteristics and proper of materials used.