prior to the disturbance was at 0200 U.T., and the most probable values for subsequent hours have been derived from this value and results recorded on the control days. The differences, Δf , between the measured and probable values of f_oF_2 at each hour are shown in Fig. 3. The pulse reached its maximum amplitude between 0300 and 0400 U.T., the time of day in July when f_oF_2 normally reaches its maximum value at Singapore.

Differences between the measured and probable values for all hours between 0200 and 1200 U.T. on each day in July have therefore been examined for similar pulses but none was found. The enhanced ionization of the F2 layer on July 10 can therefore reasonably be attributed to the effects of the solar flare.

The work described was carried out as part of the programme of the Radio Research Board. The work is published by permission of the Director of Radio Research of the Department of Scientific and Industrial Research.

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¹ Clarke, C., and Shearman, E. D. R., *Wireless Eng.*, **30**, 211 (1953).

² Minnis, C. M., Bazzard, G. H., and Bevan, H. C., *J. Atmos. Terr. Phys.*, **9**, 233 (1956).

³ Minnis, C. M., and Bazzard, G. H., *Nature*, **181**, 690 (1958).

Observations of Atmospheric Radio Noise

RECENT observations of radio noise from the upper atmosphere mainly at a frequency of 5 kc./s. have shown that it appears frequently to come from sources of limited geographical size. For example, records of the noise amplitude at places only 1,000 km. apart differ considerably in their time variations, while directional measurements of the apparent noise sources have suggested that they are sometimes as small as 500 km. in extent¹⁻³.

Yet, although the illumination of the Earth by this radiation in the Australian area appears to be both patchy and sporadic, its occurrence is clearly associated with world-wide disturbances of the geomagnetic field. It is therefore of some interest to examine any evidence for a world-wide noise pattern. Aarons, Gustafsson and Egeland⁴ have reported observations of radio noise in the kilocycle region at Kiruna, Sweden. They detected the radiation mainly in two bands centred at about 750 c./s. and 2.5 kc./s. between the hours 0600 and 1900 G.M.T. on December 5, 1958.

Examination of routine records of radiation amplitude in the band 4 kc./s.-6 kc./s. obtained at Camden, New South Wales, has shown that following a geomagnetic sudden commencement (S.S.C.) at 0035 G.M.T., December 4, 1958, a noise storm began suddenly at 1250 G.M.T. on the same day and lasted until 2200 G.M.T. on December 5, 1958. As found on many other occasions at Camden its beginning coincided with a bay-like variation in the magnetic record. Fig. 1 shows a comparison of the Kiruna and Camden geomagnetic and noise records. The early

Fig. 1. Comparison of geomagnetic and very-low-frequency noise records (December 4, 1958) from Kiruna, Sweden, and Camden, New South Wales

part of the noise storm was apparently not recorded at Kiruna although this could have been due to the different recording technique used at the two places.

It therefore appears likely that there is a world-wide pattern of noise illumination during geomagnetic disturbances, although more examples will be needed to confirm this. The study of this pattern may be of considerable importance because of the possibility that it represents an image of the disturbed regions of the outer atmosphere which are the sources of auroral particles. Investigations of whistling atmospherics have led to the belief that they are guided by ionization ducts in the outer atmosphere, probably lying along the geomagnetic field lines⁵. These magneto-ionic ducts will also guide any radiations in the kilocycle frequency band which are generated in the outer atmosphere and will thus project an image of the radiation sources on to the ionosphere. The radiation itself is likely to be caused by emission from fast charged particles traversing the plasma of the outer atmosphere.

Future studies of the world image at 5 kc./s. may be made either with a network of ground receivers or with satellite receivers. For an instantaneous picture, ground receivers would be necessary since a satellite takes 24 hr. to scan the whole Earth, whereas the average duration of noise bursts is only about 3 hr. Also, the geographical spacing between successive orbits is considerably greater than the scale of the fine structure of the image so far established³. Satellite and ground-based techniques are thus complementary and it is planned at this laboratory to make use of both.

The geomagnetic records of Toolangi Geomagnetic Observatory were supplied by the Commonwealth Bureau of Mineral Resources.

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¹ Ellis, G. R. A., *Planet. Space Sci.*, **1**, 253 (1959).

² Ellis, G. R. A., Cartwright, D. G., and Groves, J. R., *Nature*, **184**, Supp. No. 18 (1959).

³ Ellis, G. R. A., *J. Geophys. Res.* (in the press).

⁴ Aarons, J., Gustafsson, G., and Egeland, A., *Nature*, **185**, 148 (1960).

⁵ Helliwell, R. A., 'Agard' Symposium on the Upper Atmosphere, Paris, May 1959.