and (4652), 182, 1792-1793

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~~It is suggested that a process of this type might account for the auroral break-up phenomenon, and that the vertically accelerated electrons are the cause of the X-rays which have been reported as appearing when quiet arcs break up into active forms[4]. The display will continue until the voltage has been discharged.~~

~~It is interesting to note that during daytime, N is so much larger that this discharge would occur much more rapidly without the production of extra ionization, so that aurora would be expected to be a night-time phenomenon. The same reasoning might explain the summer minimum in auroral activity. To explain the equinoctial maximum, we must remember that there are, in fact, two 'circuits' in parallel, one in each hemisphere. During the northern winter, most of the discharge will occur through the more highly conducting southern ionosphere, and only near the equinoxes will the two conductivities become nearly equal. Another interesting consequence of this mechanism is that the detailed form which an auroral display takes might be expected to be dependent on the local ionospheric conditions existing before the display begins. This point could be fairly easily checked.~~

~~It must be said that the foregoing remarks in no way pretend to form a theory of aurora. They have been presented merely to direct attention to what may prove to be a useful line of thought. Many questions of auroral behaviour have been left unanswered, and it is hoped that a quantitative examination of the validity of the process, which is now under way, might provide some of the answers.~~

~~I am indebted to my colleagues at the Geophysical Institute, and especially to Dr. C. T. Elvey, for stimulating discussion of this material.~~

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~~University of Alaska,~~
~~College, Alaska.~~

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Health Hazards from Powerful Radio Transmissions

FOR many years radio-frequency heating has been used under controlled conditions for medical purposes. It is clear that radiation from a powerful transmitter might also cause heating of body tissues, and this, if excessive, would be harmful. While precautions have always been necessary to prevent this, the problem has recently become more important, since the powers and aerials now used are such that levels of field-strength considered to be dangerous can occur at some distance from the transmitter. In fact, this may be an important consideration in siting powerful transmitters.

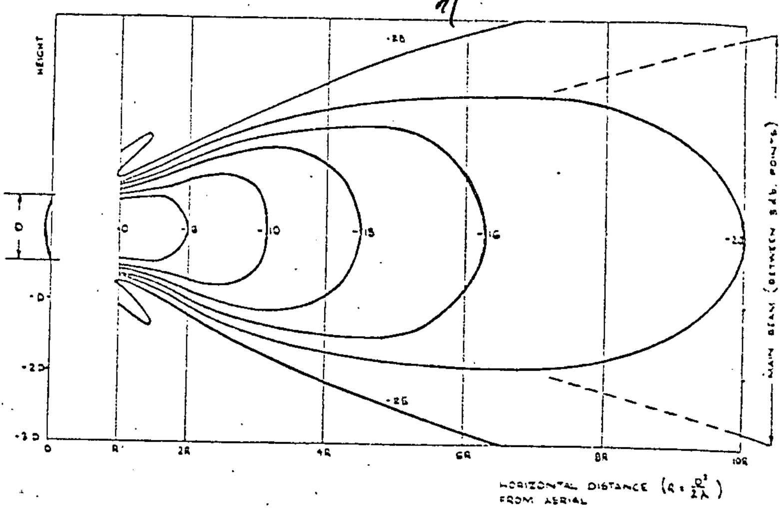

Fig. 1. Field-strength contours (in decibels) due to paraboloid of diameter D in free space

The level of field-strength which is dangerous was discussed by Schwan and Li[1]. They state that the maximum steady flux tolerated by the body is 30 mW./cm.^{2} for frequencies less than 500 Mc./s., 10 mW./cm.^{2} for frequencies between 1,000 Mc./s. and 3,000 Mc./s., and 20 mW./cm.^{2} for higher frequencies; for short exposures a much greater flux can be tolerated, for example, 300 mW./cm.^{2} for 1 min. It is of interest to predict, for particular powers and aerials, the positions at which the field will exceed the critical value.

Consider a simple aerial, a paraboloid fed by a horn; and assume that the gain of the horn is 8 db. (relative to an isotropic radiator), and the field at the edge of the reflector is 10 db. less than the field at the centre. The field outside the reflector will be less than this. It follows that, except in the region between the horn and the reflector, the direct field from the horn can be taken to be less than it would be if the horn were an isotropic radiator. This enables us to specify a 'danger distance' from the horn, for example, 3 m. for a horn radiating 10 kW. It is clear, therefore, that the danger area due to direct radiation from the feed is small.

This does not apply to the danger area due to the main field of the aerial. Fig. 1 shows the rough shape of the main field at distances between R and $10 R$ from the aerial, where R is the 'Rayleigh distance', $D^2/2\lambda$, D being the diameter of the aerial. The contours are drawn relative to the 'maximum power flux'. This is taken to be the power flux on the axis at the Rayleigh distance. It is approximately equal to $2 \cdot 3P/D^2$, where P is the power. The power flux will in fact exceed this by up to $3\frac{1}{2}$ db. at some positions within the Rayleigh distance[2].

If P is 20 kW., D is 10 m., and λ is 35 cm. (reasonable parameters for a tropospheric scatter system), then the maximum power flux is 46 mW./cm.^{2}, and R is 141 m. If we add a factor of safety of 4 to Schwan and Li's figure of 10 mW./cm.^{2}, then the safe contour is 13 db. less. If the mean height of the aerial is 10 m. above the ground and the ground is level, then the whole of the ground between 270 m. and 620 m. (say half a mile) in front of the aerial is within the danger zone, since the flux exceeds the safe flux at heights below 2 m. This would normally by unsatisfactory. It can be remedied either by increasing the mean height of the aerial to 14 m.

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by tilting the aerial upwards by 0·45°, that is, about one-fifth of a beam-width. Such an aerial could therefore safely be placed on a cliff overlooking the sea, or with ground sloping away in front of it at an angle exceeding 0·45°.

The field at distances from the aerial less than the Rayleigh distance is largely confined within a cylinder the base of which is the reflector. The field below this cylinder is generally about the same as it is at the same height at the Rayleigh distance[2]. For example, for the aerial considered above (10-m. reflector, mean height 10 m., wave-length 35 cm.) the field at a height of 2 m. above the ground varies as one moves away from the aerial but is always more than 20 db. less than the 'maximum power flux' up to a distance of 200 m.; as one moves farther away, it increases to about 10 db. at 340 m., and then decreases continuously, reaching 14 db. at 680 m. and 20 db. at 1,380 m.

It is worth pointing out that the fields computed are those in free space. The ground will reflect radiation, the reflexion coefficient being dependent on wave-length, polarization, and the dielectric constant and roughness of the ground[3]. If the reflexion coefficient is −1 (horizontal polarization, smooth earth), then the field-strength at some points will be 6 db. greater than that in free space. This would account completely for the 'factor of safety' of 4 taken into account above.

An ionospheric scatter system on, say, 40 Mc./s., would not in general have such a large danger area, since the maximum power flux would be smaller and the allowable power flux would be greater. dar systems will also have a smaller maximum wer flux, and so are unlikely to be dangerous except near the axis of the beam. Even right in the beam, there will be no danger provided that the aerial is kept scanning. It might be worth while to point out that medium powers and small aerials can be dangerous; for example, 100 watts and 1 metre diameter gives a maximum flux of 23 mW./cm.², well above the tolerable limit; the Rayleigh distance is, however, quite small, being only 5 m. for a wave-length of 10 cm.

All these conclusions are subject to review in the light of new biological findings. The work of Schwan and Li[1] seems rather conjectural, but is the only solid basis available at present, apart from serious effects caused by much higher power densities[4]. It is clear that the adequate application of safety precautions would be much facilitated by a simple instrument which indicates whether or not a field of, say, 2 mW./cm.² is being exceeded. It is also of importance for pulse radar to know whether a strong field, say, 3 kV./m., lasting for a microsecond or so, can do any harm to the body apart from its heating effect.

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Oct. 29.

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Bismuth–Tellurium Photo-voltaic p–n 'Sandwich' Layer

IT has been fairly well established[1,2] that bismuth telluride changes conductivity type[1,2] with the excess of tellurium over stoichiometric proportion between 1 and 2 atomic per cent[3]. It has been assumed that each excess Bi(Te) atom replacing the Te(Bi) atom in the single crystal of $\mathrm{Bi_2Te_3}$ behaves as an ionized acceptor (donor)[1-3].

It seemed to me that if the conductivity type of a layer of semiconductor, approximately 1μ thick, evaporated on to the surface of a plate of insulating material would change from p (or n) to n (or p) in the direction perpendicular to the plate surface, it would possess the photo-voltaic property. An attempt to process such a layer was successful. I then reasoned in the reverse direction. Both the fact that the layer has shown the photo-voltaic property and the method of its preparation have suggested that the layer is of a 'sandwich', p–n barrier type.

A layer of bismuth was evaporated *in vacuo* on to the surface of a glass plate 8 cm. × 2 cm., covering little more than half of its length. Then a layer of tellurium was evaporated on to the uncovered portion of the plate overlapping the end section of the bismuth film in the middle area of the plate. Thus, the central portion was a 'sandwich' type Bi–Te layer of the area of ½ cm. × 2 cm., while the remaining bismuth and tellurium portions served as leads which enabled the connexion of the 'sandwich' layer in series with a galvanometer and eventually with a battery.

The layer was then heated *in vacuo* up to a temperature of about 150–200° C. for a few minutes. After removing it from the evaporator, the layer showed the following properties in atmospheric air. Its dark resistance was about 7,000 ohms at room temperature. Under an intensity of illumination of 25×10^{-5} lumens/mm.² given by a tungsten lamp it decreased by about 15–20 per cent. The photo e.m.f. generated by the same radiation intensity amounted to about 50 millivolts. The bismuth electrode acquired positive potential on illumination in respect to the tellurium electrode. The response time was of the order of a few msec., proving the effect to be photo-electric.

Tentatively, these effects could be accounted for in the following way. As soon as crystallites of bismuth in the 'sandwich' portion of the layer come in contact with those of tellurium, diffusion of the tellurium (bismuth) atoms, enhanced by elevated temperature, into the bismuth (tellurium) crystallites occurs. It is presumed that one, or both, of two things may then happen: either tellurium (bismuth) crystallites with bismuth (tellurium) wrong site atoms, acting as acceptors (donors), or bismuth (tellurium) rich bismuth telluride ($\mathrm{Bi_2Te_3}$) crystallites are formed, in the latter case with (0001) planes parallel to the glass plate surface.

In both cases p–n barriers would be formed, with the p-type material on the side of the bismuth electrode, and the n-type material on the side of the tellurium electrode. Electron (hole) type conductivity in the planes parallel to the surface of the plate glass may also occur in the bismuth (tellurium) portion of the sandwich layer. Photo-conductive layers of $\mathrm{Bi_2Te_3}$ have been made by other investigators[4-5], but no details have been revealed.

The above method could perhaps be applied to other compounds characterized by low temperature