THE DECAMETRIC RADIO EMISSIONS OF JUPITER

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Summary

The cyclotron theory of the decametric radiations of Jupiter is examined in detail. Providing Jupiter is surrounded by an extensive ionized exosphere, it is shown that the theory accounts for the observed variation in the number of radiation bursts with planetary rotation, their polarization, and their spectra. It is found also that the average power of the bursts and their polarization are functions of the number of bursts.

The configuration of the Jupiter magnetic field is discussed. It is suggested that this deviates from that of a dipole with a maximum deviation in dip angle of 13° between longitudes 200° and 260° below a height of about 35 000 km.

I. Introduction

It has recently been proposed that the decametric radio emissions of Jupiter, like the V.L.F. radio emissions of the Earth, are caused by cyclotron radiation from bunches of electrons trapped in a planetary magnetic field (Ellis 1962, 1963; Dowden 1962*a*). Good agreement has been obtained between the observed and expected variation of the Jupiter radiation with planetary rotation for wave frequencies near 5 Mc/s.

However, many other properties of the radiation remain to be accounted for and in this paper a more detailed comparison between the theory and the observations is made.

II. Observational Data

The observed properties of the decametric radiations which we will discuss here have been summarized recently by Roberts (1963). They are as follows:

(*a*) The radiation frequency range extends from less than 5 Mc/s to more than 35 Mc/s.

(*b*) The radiation is observed to occur in the form of bursts with a duration of about 0·2 s or longer. Sometimes quasi-continuous radiation of fluctuating amplitude lasting for some minutes is recorded.

(*c*) The probability of occurrence of bursts in a given time interval varies as the planet rotates. Between 15 and 30 Mc/s there appear to be four maxima. At frequencies less than 10 Mc/s only two of these maxima, 180° apart, are observed, while above 30 Mc/s there is only a single maximum. Figure 1 summarizes this data.

(*d*) The polarization of the radiation is elliptical with axial ratios in the range 0·2–0·8. At frequencies above 18 Mc/s approximately 90% of the bursts have right-handed polarization. At lower frequencies this percentage decreases.

(*e*) Dynamic spectra show that the bursts have a bandwidth of about 1 Mc/s or more and that the centre frequency may change with time. The direction of change appears to depend on the longitude of the planet. Figure 2 summarizes the spectral data obtained by Warwick (1961).

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III. Theory

(*a*) *Direction of Emission*

We assume that Jupiter is surrounded by an extensive ionized exosphere, the density of which, like that of the Earth, is roughly proportional to the magnetic field intensity. We assume also that, as a result of disturbances near the outer boundary of the exosphere, bunches of electrons are accelerated and thereafter travel down the high-latitude field lines. This general picture corresponds with what we know of the terrestrial exosphere (Dowden 1962*b*).

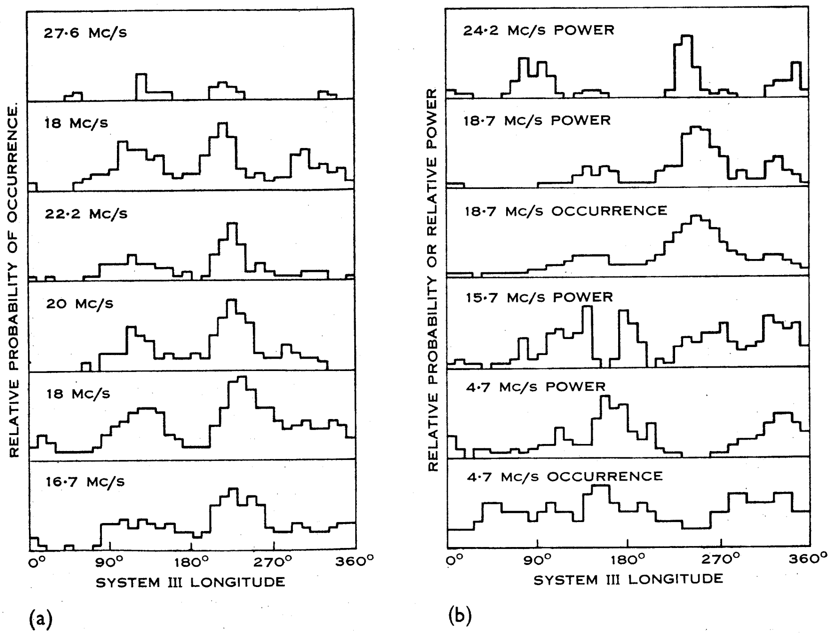

Fig. 1(*a*).—Variation of the probability of occurrence with Jupiter longitude (revised System III) for different wave frequencies (Carr *et al.* 1961).
Fig. 1(*b*).—Variation of the probability of occurrence and burst power with Jupiter longitude (revised System III) for different wave frequencies (Ellis and McCulloch, unpublished data).

Because of their helical motion in the magnetic field the electrons will emit electromagnetic radiation, the general theory of which has been given by Eidman (1958) and discussed in relation to Jupiter by Ellis (1962, 1963). Where the electrons are not highly relativistic they radiate mainly at the electron cyclotron frequency $(eH/mc)\,(1-v^2/c^2)^{\frac{1}{2}}$, the observed frequency being determined by the Doppler equation

$$f = f_H\,(1-v^2/c^2)^{\frac{1}{2}}/\{1-(nv/c)\cos\phi\,\cos\theta\}, \qquad (1)$$

where

$n = n\,(\theta, H, N, f) =$ Appleton-Hartree refractive index of the ionized medium, (2)

$\phi =$ pitch angle of the electrons,

$\theta =$ wave normal direction of the emitted radiation with respect to the magnetic field vector,

$H =$ magnetic field intensity.

Since we have assumed that the electron density is nearly proportional to H, planes of constant refractive index will be normal to the H vector and the final direction of the radiation after refraction will be given by

$$\sin \alpha = n \sin \phi. \tag{3}$$

By simultaneous graphical solution of equation (1) and (2) for θ and f it is found that radiation ahead of the electron ($0 < \theta < \frac{1}{2}\pi$) is possible only for values of θ less than

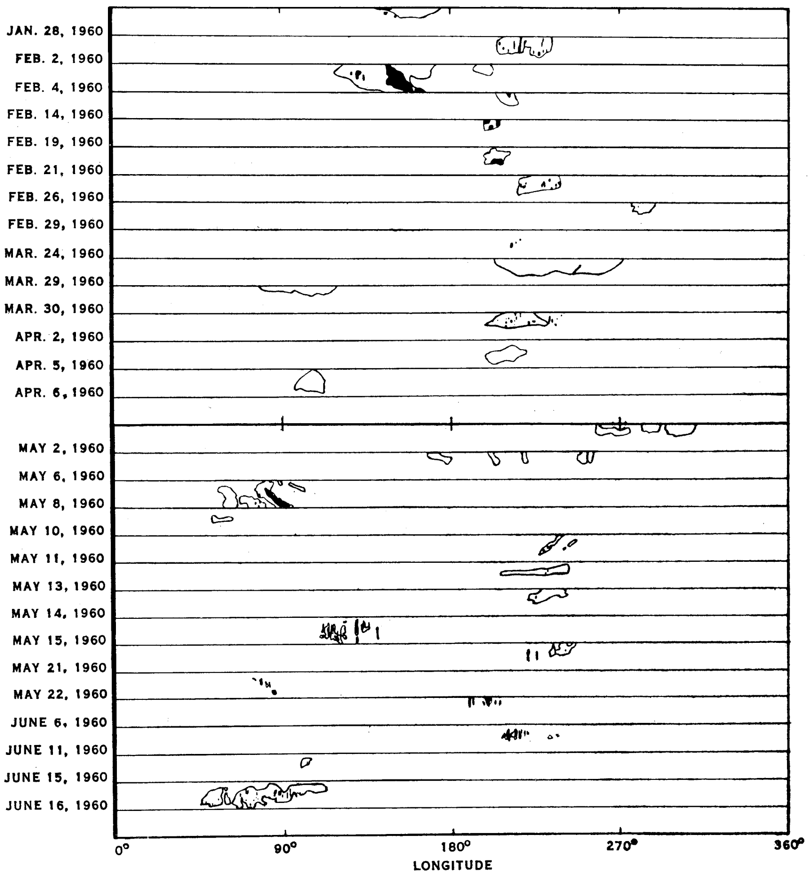

Fig. 2.—Spectra observed by Warwick (1961) plotted against longitude. The ordinate scale in each section is wave frequency with a range of 15–34 Mc/s increasing downwards.

some maximum value θ_m. Figure 3 shows a graph of the permissible values of θ and f in typical circumstances. The corresponding values of α may be calculated from equation (3). A graph of θ against α is shown in Figure 4.

It is seen that the radiation is limited to a cone whose axis lies on the magnetic field vector. The radius of the cone depends strongly on the ratio f_H/f_0 and on the pitch angle ϕ, but only to a small extent on the electron energy, providing this latter quantity is in the range 10–100 keV, with f_H/f_0 between 5 and 20 (Fig. 5).

The reason for the restriction of the forward radiation to a cone may be understood qualitatively as follows. The refractive index of the plasma is imaginary for the X-mode for frequencies between f_H and $f_x = (f_0^2 + \frac{1}{4}f_H^2)^{\frac{1}{2}} + \frac{1}{2}f_H$. Above f_x it is less than unity. Only if the velocity component of the electron in the direction of wave propagation is sufficient to produce a Doppler shift of the emitted frequency γf_H to a value greater than f_x can radiation occur. There will therefore be a least velocity for which radiation is possible directly ahead of the electron ($\theta = 0$). If v_2 is greater than this, then radiation is possible over a limited cone whose angular size is determined by the solutions of (1) and (2).

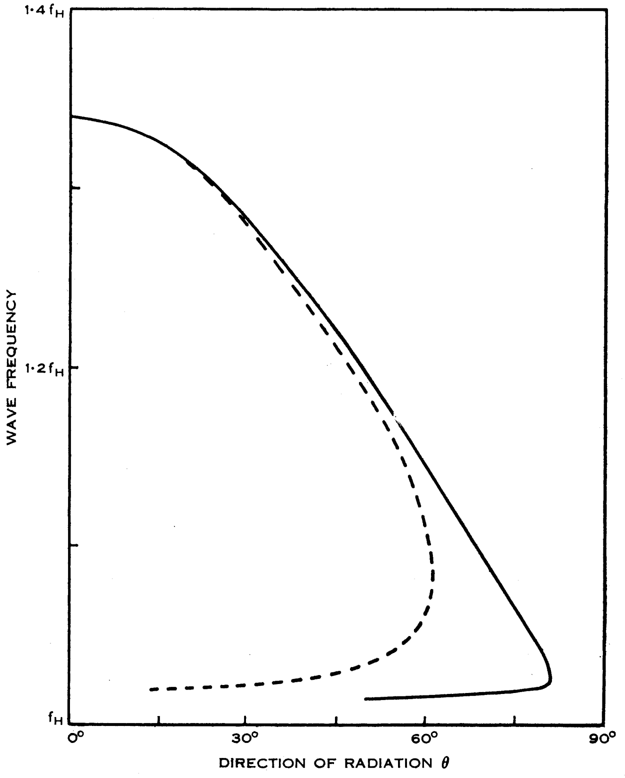

Fig. 3.—Solid line represents solutions of equations (1) and (2) giving possible values of θ and f. Dashed line represents the modification of the direction of radiation (θ) as a result of refraction (equation (3)). Electron energy 30 keV, pitch angle $\phi = 30°$, $f_H/f_0 = 10 \cdot 5$.

It is worth noting here that if one considers the rearward radiation ($\frac{1}{2}\pi < \theta < \pi$), then no such limitation exists since the refractive index is real for all frequencies less than f_H. Cyclotron radiation will therefore occur always. In addition, since the X-mode refractive index is greater than unity, radiation in this frequency range is possible in the Cerenkov mode. However, neither the backward Doppler radiation nor the Cerenkov radiation would be able to escape from a planetary exosphere, since this would require propagation through a region where $f_H < f < f_x$, i.e. one with imaginary refractive index.

The attenuation through such a region is very high for electron densities greater than about $1/\mathrm{cm}^3$. Analysis of a similar situation by Ellis (1956), for example, gave a transmission coefficient of only 4×10^{-8} for 1 electron/cm^3. This latter density is commensurate with that in interplanetary space and would be considerably exceeded in the exosphere of a planet.

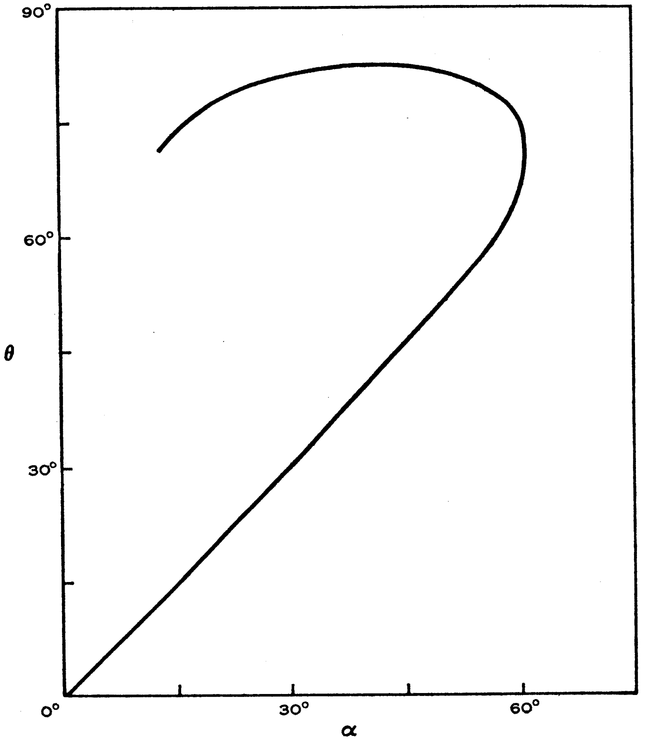

Fig. 4.—Relation between the initial direction θ and final direction α of the radiation. Conditions are the same as in Figure 3.

(b) *The Radiated Energy*

For possible values of n, f, and θ obtained from equations (1) and (2) the radiated power per unit solid angle $W(\theta)$ may be calculated using the general radiation equation of Eidman (1958) (see also Ellis 1962). $W(\theta)$ is modified by refraction and focusing in the ionized medium and we obtain the final distribution of power $W(\alpha)$ about the magnetic field vector from the relation

$$W(\alpha)\sin\alpha\,\mathrm{d}\alpha = W(\theta)\sin\theta\,\mathrm{d}\theta. \tag{4}$$

From Figure 4 it is seen that $\mathrm{d}\alpha/\mathrm{d}\theta$ is zero when $\alpha=\alpha_{\mathrm{m}}$, and hence the radiated power increases towards infinity in this direction. A graph of $W(\alpha)$ is shown in Figure 6. The width and height of the maximum at $\alpha=\alpha_{\mathrm{m}}$ is uncertain. If one considers a bunch of electrons of slightly differing pitch angles then there will be a corresponding range of α_{m}. In addition, scattering in the plasma and allowance for the finite size of the bunch would modify the profile of $W(\alpha)$ in an unpredictable way. However, we will assume here that this profile is in fact as it is shown in Figure 6, that is, the greatest amount of power per unit solid angle is emitted for $\alpha \sim \alpha_m$ and for other directions there is negligible radiation. It will be shown later that this assumption can be justified experimentally from the characteristics of the radiation spectra.

(c) *Polarization*

The major part of the radiation is emitted in the extraordinary mode and its limiting polarization after refraction may be calculated using the Appleton-Hartree theory. Since we are taking final radiation directions to be on the surface of a cone of angle α_m, the polarization will be determined largely by the value of α_m and with good accuracy we may write

$$\text{Axial ratio, } A = \mp \cos \alpha_m.$$

IV. Model of the Jupiter Magnetosphere

In order to proceed further it is necessary to consider a more specific model of the Jupiter magnetosphere. Recent observations of the decimetric radiations have led to the conclusion that the polar magnetic field intensity is in the vicinity of 15 gauss,

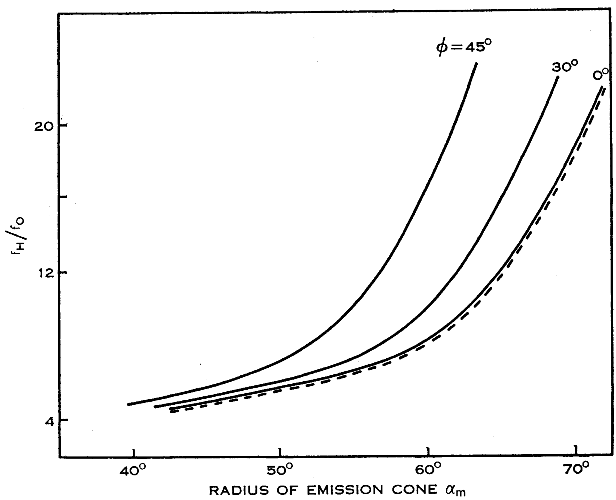

Fig. 5.—Variation of the cone angle α with f_H/f_0 for different values of the pitch angle ϕ. Solid lines, electron energy 30 keV; dashed line, electron energy 80 keV, $\phi = 0$.

that the dipole axis is inclined about 10° to the rotation axis of the planet, and that the longitudes of the poles are near 0° and 180°, System III. We assume these values. It is necessary also to define the latitudes of the magnetic field lines which the electron bunches travel. For guidance we consider the terrestrial magnetosphere. Here it is found that electron bunches appear most frequently on high-latitude field lines and that their probability of occurrence falls rapidly with geomagnetic latitude. The stronger magnetic field of Jupiter would be expected to extend relatively further into the surrounding space than that of the Earth, and we assume that the corresponding magnetic latitudes on Jupiter range from 75° to 85°. The actual range taken does not affect the conclusions in any important way. By assuming that the electrons travel along field lines of lower magnetic latitudes, for example, it is found only that the computed density of the plasma through which they travel is slightly greater. For reasons which will appear later we need to specify the way the probability of occurrence of bunches varies with magnetic latitude, and for simplicity we take a linear increase with latitude with zero probability at magnetic latitude 75°.

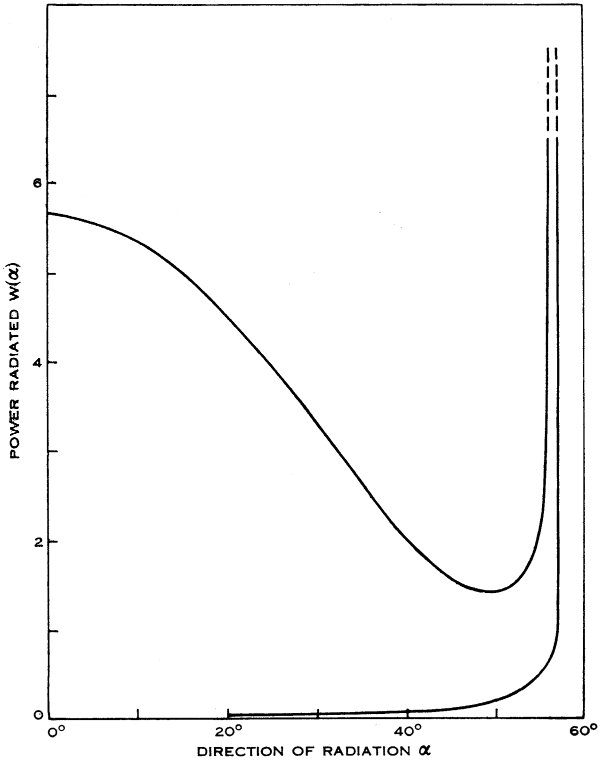

Fig. 6.—Angular distribution of the cyclotron radiation after refraction. Electron energy 30 keV, pitch angle $\phi = 30°, f_H/f_0 = 8 \cdot 0$.

We assume further that within an electron bunch all the electrons have the same pitch angle but that the pitch angles vary from bunch to bunch; all pitch angles occurring with equal probability. This property is observed in the case of terrestrial electron bunches (Dowden 1962*b*). In addition, we take the electron energies to be in the range 10–100 keV, as is observed for the Earth.

V. Discussion

(*a*) *Probability of Occurrence of Radiation Bursts*

We wish to obtain theoretically the variation in the probability of observable radiation bursts as the planet rotates if we assume that electron bunches may occur with equal probability in all magnetic longitudes. To do this we need to consider the effect of different electron pitch angles on the observability of the radiation. We have seen in Figure 5 that the angle of the radiation cone is strongly dependent on the pitch angle, and this relation may be made more specific by using equations (1) and (3). We have from equation (1)

$$\cos\phi = \frac{1-\gamma y}{\beta(n^2-n^2\sin^2\theta)^{\frac{1}{2}}}, \qquad y = \frac{f_H}{f},$$

$$= \frac{1-\gamma y}{\beta(n^2-\sin^2\alpha_{\mathrm{m}})^{\frac{1}{2}}}, \qquad \gamma = (1-v^2/c^2)^{\frac{1}{2}}. \tag{5}$$

For a given radiation frequency and electron energy, y and n are very nearly invariant

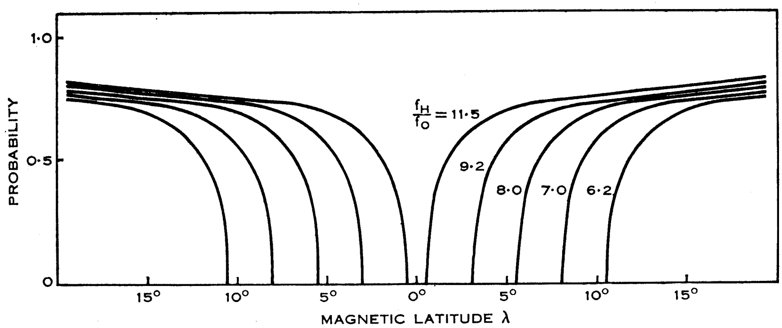

Fig. 7.—Variation of the probability of observation of radiation bursts with magnetic latitude if the electron bunches are confined to field lines which terminate at magnetic latitude 75°. All pitch angles are taken into account. Electron energy 30 keV, wave frequency 20 Mc/s.

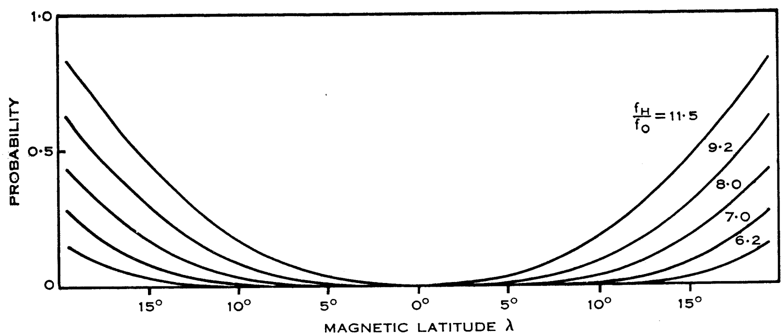

Fig. 8.—Variation of the probability of observation of radiation bursts with magnetic latitude if the field line latitudes vary from 75° to 85°. The probability of bunches is assumed to be zero at magnetic latitude 75° and to increase linearly with latitude between 75° and 85°. Other conditions same as in Figure 7.

with respect to changes in α_{m}. If we assume that bunches of electrons with all pitch angles may occur with equal probability, we have for the number $\mathrm{d}N$ of bunches with pitch angles in the range ϕ to $\phi+\mathrm{d}\phi$.

$$\mathrm{d}N = \sin\phi\,\mathrm{d}\phi,$$

or with equation (5)

$$dN = \frac{(1-\gamma y)\sin\alpha_m \cos\alpha_m}{\beta(n^2-\sin^2\alpha_m)^{3/2}} d\alpha_m. \tag{6}$$

Equation (6) gives the number of bunches travelling along a given field line whose

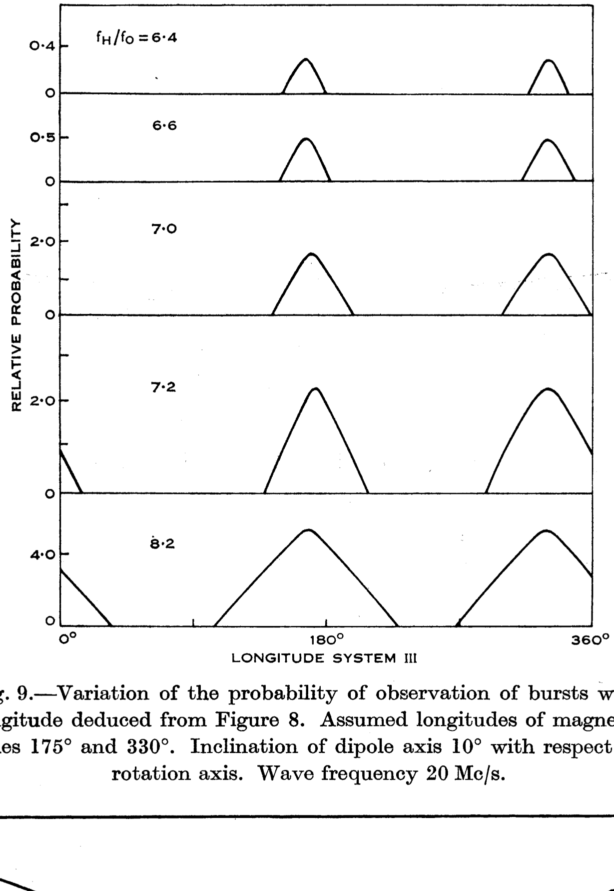

Fig. 9.—Variation of the probability of observation of bursts with longitude deduced from Figure 8. Assumed longitudes of magnetic poles 175° and 330°. Inclination of dipole axis 10° with respect to rotation axis. Wave frequency 20 Mc/s.

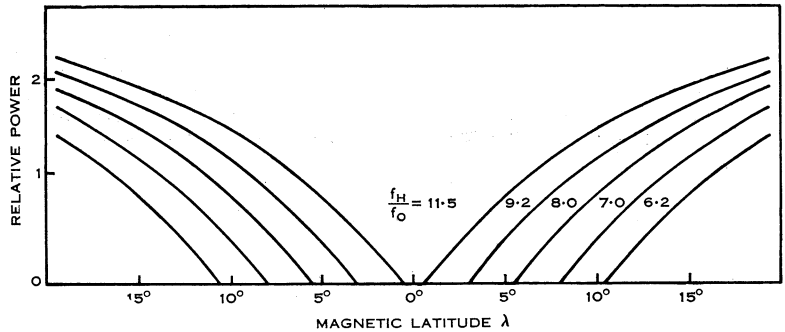

Fig. 10.—Variation of the power of the bursts with magnetic latitude. With same conditions as Figure 7.

radiation is observable at a particular frequency and at an angle α_m with respect to the field line direction at the point of emission. We transform this coordinate system into one based on magnetic latitude and longitude. If the inclination of the magnetic field line along which the bunches travel is β with respect to the magnetic axis, then the magnetic latitude λ of the radiation cone at a magnetic longitude L different from that of the field line may be obtained by simple spherical trigonometry, that is,

$$\cos a_{\mathrm{m}} = \cos L \sin \beta \cos \lambda + \cos \beta \sin \lambda. \tag{7}$$

Substitution of equation (6) in equation (7) and integration with respect to magnetic

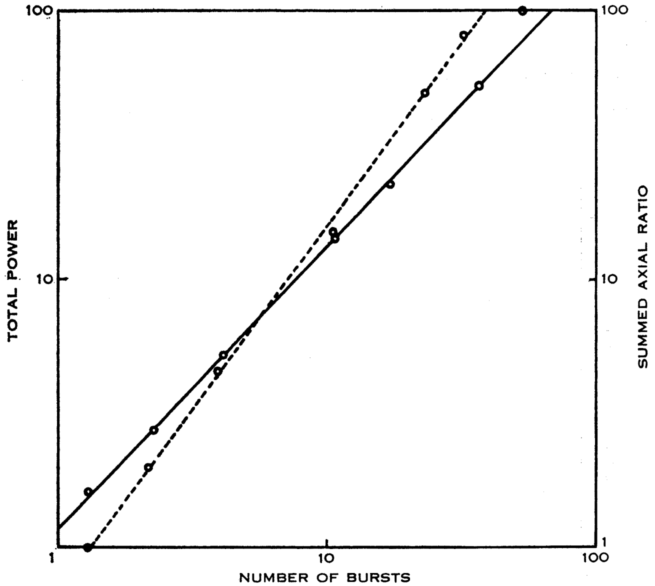

Fig. 11.—The relation between the total power (dashed line), the summed axial ratio (full line), and the number of bursts in any longitude interval is found to be almost logarithmic. Theoretical points are indicated thus ○.

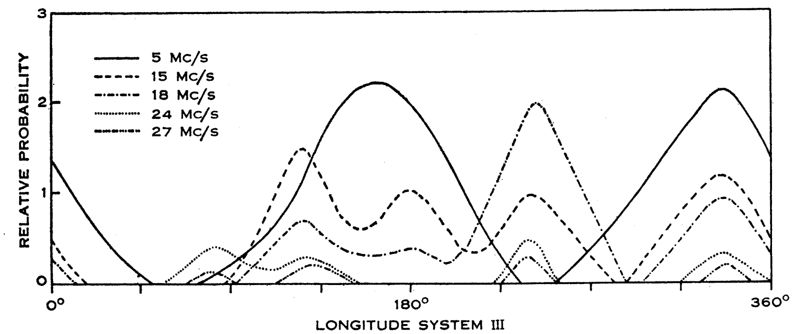

Fig. 12.—Smoothed occurrence and power data from Figure 1.

longitude yields the number of bunches N_λ whose radiation may be observed in a given magnetic latitude interval $d\lambda$ at latitude λ. Graphs of this function for different values of f_H/f_0 are shown in Figure 7.

If we assume that the number of bunches increases linearly with the magnetic latitude of the field lines then these functions are modified to the form shown in Figure 8.

It may be seen by inspecting Figure 8 that, if the observer's magnetic latitude varies with rotation of the planet as a result of a difference between the directions of the rotation and magnetic axes, then the number of radiation bursts observed will vary in a cyclic way with a maximum at each of the magnetic pole longitudes. Figure 9 shows the computed variation for different values of the parameter f_H/f_0 at a particular frequency for the assumed model. For observations at a given frequency, f_H will be determined, and comparison with the observed variation may hence be used to establish the value of f_0 which corresponds to this value of f_H. f_H, in turn, for a given magnetosphere gives the emission height.

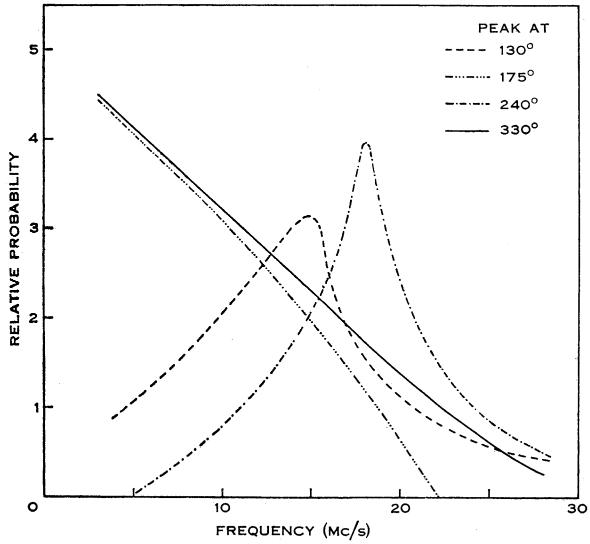

Fig. 13.—Variation of the amplitudes of the occurrence maxima with frequency.

(b) *Variation of the Total Power of the Bursts*

It may be shown from Eidman's equation (Eidman 1958) that to a good approximation the radiated power varies as the pitch angle of the electrons according to $W \propto \sin^2\phi$. We then have for the power radiated by dN electrons, using equation (6),

$$W\,dN \propto \sin^3\phi\,d\phi. \tag{8}$$

Proceeding as before we may compute the total power W_λ radiated in a latitude interval $d\lambda$ by combining equations (6), (8), and (7) and integrating with respect to longitude. The resulting curves of W_λ for different values of f_H/f_0 are shown in Figure 10.

If we assume, as before, that the probability of electron bunches varies linearly with magnetic latitude then it is found from Figures 8 and 9 that the total power radiated, W, is related to the total number of bursts N in the same latitude interval according to the good approximation

$$W \propto N^{x}, \qquad \text{where } x = 1\cdot 3,$$

and hence the mean power of the bursts

$$\overline{W} = W/N \propto N^{0\cdot 3}.$$

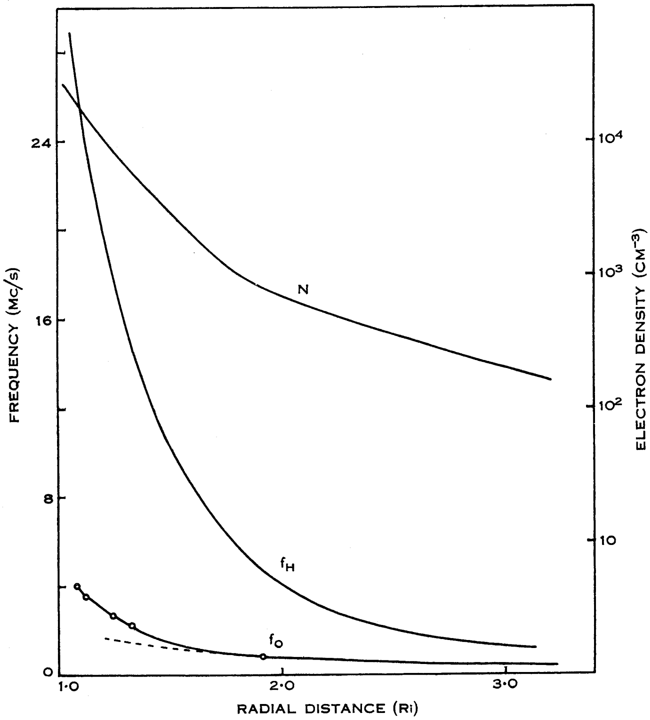

Fig. 14.—Variation of the electron density with height deduced from comparison of Figures 9 and 12. The dotted line indicates the extrapolated value of f_0 to lower heights if $f_0 \propto \sqrt{H}$, i.e. $N \propto H$. Calculated points are shown thus ○.

It is therefore a conclusion of the theory that the mean power of the bursts varies with the number of bursts, that is, when the bursts are more numerous they are stronger. The relation between W and N is illustrated in Figure 11.

It should be noted that errors can arise in the counting of bursts because of the possibility of their simultaneous occurrence. The effect of such errors will be to make the observed value of the parameter x larger than that calculated here. Accurate statistics on the occurrence and duration of the bursts should permit the errors in counting to be estimated.

(*c*) *Polarization*

As mentioned in Section III, the polarization of the radiation is given with good accuracy by the relation

$$\text{Axial ratio, } A = \mp \cos \alpha. \tag{9}$$

The summed axial ratio $A_N = \Sigma\,|A|\,\mathrm{d}N$ may be obtained by combining equations (6), (7), and (9) and integrating with respect to longitude. If we assume, as before, that the probability of electron bunches varies linearly with latitude, it is found that the summed axial ratio A_N is related to the number of bursts N that occur in the same latitude interval according to the relation.

$$A_N \propto N^y, \qquad \text{where } y = 1\cdot 05,$$

and hence the mean of the modulus of the axial ratio of the bursts

$$|\overline{A}| = A_N/N \propto N^{0\cdot 05}.$$

The relation between A_N and N is illustrated in Figure 11.

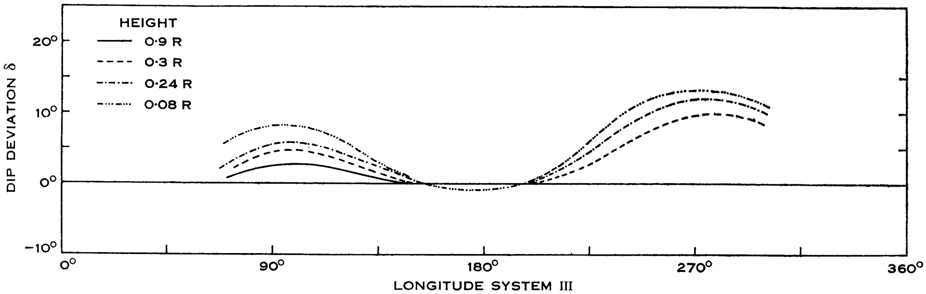

Fig. 15.—Change in dip angle δ at different heights needed to produce anomalous peaks in the probability curves of Figure 1 with density model of Figure 13. The heights correspond to wave frequencies of 5, 15, 20, and 27 Mc/s.

(d) *Comparison with the Observations*

Reference to Figure 1 shows that the observed probabilities of occurrence of bursts and their power do not in general vary with longitude in the quasi-sinusoidal way expected for a regular dipole magnetic field (Fig. 9). Only at 4·7 Mc/s are there just two maxima approximately 180° apart. These are more obvious on the total power curves. To account for the additional or anomalous maxima at higher frequencies it is necessary to modify the dipole magnetic field assumed so far.

These anomalous variations in the probability of occurrence may clearly be produced by a deviation in the magnetic dip from that of a dipole in the latitudes and longitudes where the emission takes place.

If the angular amount of this deviation is δ in the plane of the magnetic meridian at a given height for which the ratio f_H/f_0 is constant, then the effect is to change the latitude datum of the corresponding probability curve in Figure 8 by an amount equal to δ. It may be seen from Figure 8 that, with the assumed model, a latitude shift of the probability curve by a few degrees can produce a considerable change in the observed probability of occurrence.

To identify which probability or power maxima are associated with the poles the data of Figure 1 are shown smoothed and superimposed in Figure 12. There appear to be four distinguishable maxima at 130°, 175°, 240°, and 330° longitude respectively. It might be expected that those at 175° and 330° correspond with the poles if these latter are taken to be at 0° and 180°. Also, we note that the amplitudes of these two maxima decrease rapidly with wave frequency while the amplitudes of the others increase in the frequency range from 5 to 20 Mc/s (Fig. 13). Now any magnetic anomalies would normally increase rapidly in their effects with decreasing radial distance, that is, with increasing wave frequency, while, conversely, the magnetic field would become more like that of a dipole at greater distances. We therefore have a second criterion for selecting the polar and anomalous maxima. Again we find from Figure 12 the former to be those at 175° and 330°. If the polar maxima can be identified then the variation in the electron density with height may be estimated from Figure 9 as follows.

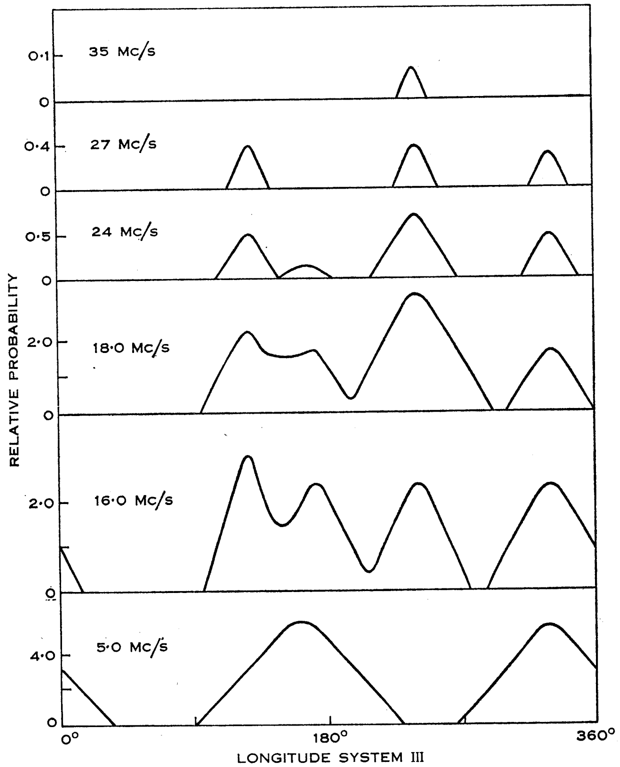

Fig. 16.—Calculated probability curves including dip anomalies of Figure 15.

For each wave frequency the value f_H is known, very nearly, and the expected variation in the probability of occurrence for different values of f_H/f_0 can be computed. Comparison of the calculated probability curves (Fig. 9) with those observed gives f_H/f_0 and hence f_0. In addition, the height for which this value of f_0, and consequently the electron density, is appropriate is obtained from the known variation of f_H with height.

If the electron density is specified in this way the dip anomalies needed to account for the anomalous occurrence maxima may be obtained easily from Figure 8. The expected variation of probability and power with longitude, including anomalies, may then be computed. The calculated electron densities are shown in Figure 14, the dip anomalies in Figure 15, and the resulting expected probability curves in Figure 16. The distribution of the axial ratios of the polarization ellipses is shown in Figure 17.

It is seen that the theoretical curves agree well with those observed for all frequencies in their general shape. Accurate matching between the properties of the

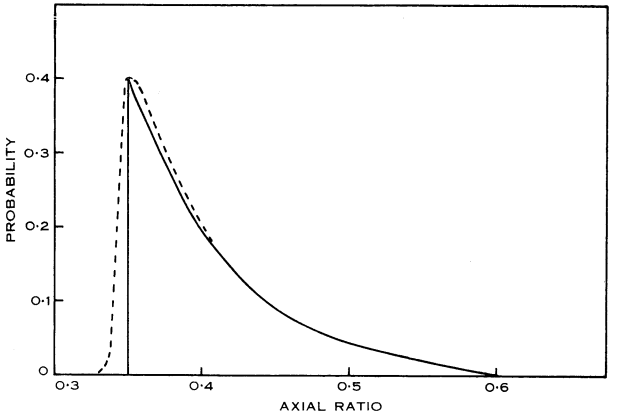

Fig. 17.—Probability of occurrence of axial ratios at a wave frequency of 10 Mc/s. Full line 30 keV, dashed line 20–80 keV.

model and the observations must await more complete data. However, it should be noted that, since in the cyclotron theory the observability of a burst depends on the inclination of the field line at the point of emission, any observed pattern in the occurrence of bursts may be accounted for by slight suitable adjustments of the magnetic field configuration of the type discussed here. This adjustment need not be confined, of course, to local variations in the dip angle but may include the moving of the dipole axis to an asymmetric position with respect to the rotation axis, as suggested by Warwick (1963).

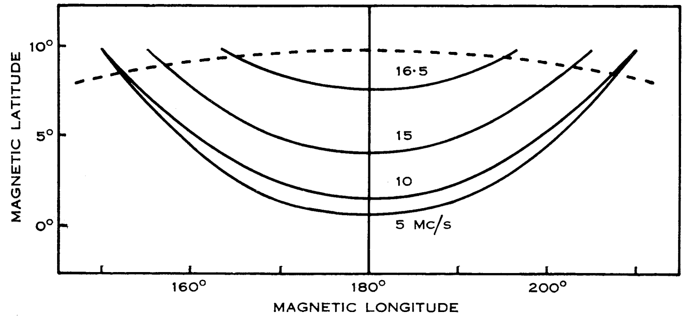

Fig. 18.—Location of the radiation cones for electron bunches travelling along the $\lambda = 77\cdot5°$ field line at a magnetic longitude of 180° and having pitch angles of 20° at the 5 Mc/s level. The dashed line shows the variation of the observer's magnetic coordinates with rotation of the planet.

(e) *Spectral Variations*

Unlike the observations and the expected properties of the radiation so far considered, the spectral observations give information about individual occurrences rather than their time averages. We therefore need to discuss the distribution of the radiation from electron bunches travelling down a single field line.

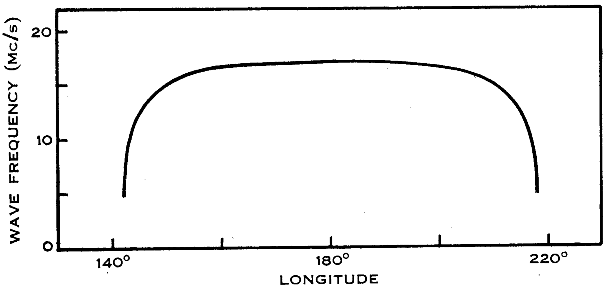

Fig. 19.—Variation of the observed frequency with rotation from Figure 18.

Different wave frequencies will be emitted at different heights for which the direction of the magnetic vector and the ratio f_H/f_0 are determined from the characteristics of the model and the deduced electron density distribution. The angle of the radiation cone α_m will therefore vary with frequency, and the magnetic coordinates of the cone at any frequency may be obtained from equation (7). Figure 18 illustrates

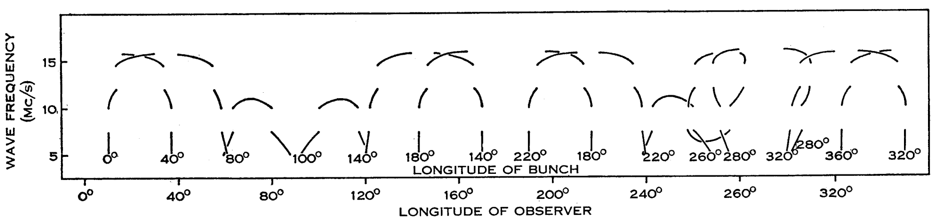

Fig. 20.—Possible frequency–longitude variations when bursts in all magnetic longitudes are taken into account. $\lambda = 77 \cdot 5°$ field line and the pitch angles of the electrons are 20° at the 5 Mc/s level.

the positions of the radiation cones at different frequencies for bunches of electrons in a specified field line. It may be seen that, as the latitude and longitude of the observer change with the rotation of the planet, the observed frequency will change with time, provided that the stream of electron bunches lasts for the duration of the observations.

The corresponding frequency-time curve is illustrated in Figure 19. If the radiation cone from an individual bunch is not of negligible angular thickness as we have assumed, then within the slowly varying frequency-time function produced by the rotation of the planet much more rapid variations could be observed. These would be produced by the change in radiated frequency with time as the individual bunch travels down the field line (see Ellis 1962).

In addition the slow variation of Figure 19 would be frequency broadened into a band whose width is a function of the cone thickness. Examination of the observed spectra of Figure 2 shows that many are narrow in frequency. It is therefore deduced that Figure 6 represents well the actual distribution of power from an electron bunch.

Figure 20 shows the computed spectra as a function of longitude when bursts which can occur in all magnetic longitudes are taken into account. The wide variety in the frequency-time slopes of the observed spectra (Fig. 2) and their variation with longitude would seem to be met by the theory.

Each of the spectra shown in Figure 20 corresponds to the emission from a succession of electron bunches or an electron stream of constant pitch angle confined to a given field line and lasting for the duration of the spectrum. If the pitch angle of the electrons at a given height is not constant during the life of the emission, or if the cross-sectional area of the stream is not infinitesimal then the spectrum will be broadened. Hence it is possible by inspection of the observed spectra to set limits on the area of the stream and consequently on the angular size of the source as seen from the Earth.

Some of the spectra in Figure 2, for example, have a longitude width at a single frequency of only 5°. Even if we assume that the pitch angles were constant and that the electron stream were confined to a single latitude, this implies that the longitude spread is only 5°. Relaxation of these restrictions would lead to a smaller value. The observed spectra therefore indicate that the sources of the radiation may be very small. The more diffuse spectra shown in Figure 2 can be accounted for by larger sources or variation in the pitch angles.

It may be expected that a close study of the characteristics of the spectra will provide detailed information on the source sizes.

VI. Conclusions

It appears that the properties of the decametric radiations of Jupiter may adequately be explained on the basis of cyclotron radiation from electrons in a magnetosphere which is generally similar to that of the Earth. A necessary feature of this explanation is that Jupiter is surrounded by an ionized exosphere and that its magnetic field configuration deviates somewhat from that of a dipole in at least two areas of the planet. The theory shows that it is possible to deduce the density of the exosphere and the extent of the magnetic anomalies from the observations.

It is pointed out that the observation of the variation of the power of the bursts with planetary rotation provides a more accurate measure of the characteristics of the Jupiter magnetosphere than their rate of occurrence or their polarization.

Future observations should include measurement of the power. However, adequate statistical information on the bursts would permit more accurate deductions to be made from the occurrence data.

Observations of the spectra of the bursts are likely to provide specific information on the characteristics of the electron bunches and streams.

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