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Pencil Beam Radar for Ionospheric Research

A HIGH frequency pencil beam radar for ionospheric research has been in operation for some time on Bribie Island near Brisbane, Australia. The beam is formed as the product of the polar patterns of a 1 km arm used for transmitting and another 1 km arm at right angles for receiving, the whole array forming a 1×1 km cross. The effective beam is about 4° wide at 4 MHz. Each polar pattern is able to have its peak shifted up to 20° off vertical (at 4 MHz) using digital phase shifting. Each of ten transmitting aeriels is a spread dipole and each of ten receiving aeriels is a crossed delta with 90° phase shifters between the two arms. The radar operates on frequencies near 2, 4 and 6 MHz, using ordinary or extraordinary rays as desired.

The beam steering operates under automatic digital control or under the control of a PDP-11 computer. Digital recording on magnetic tape of angles of arrival, phase and amplitude is possible directly or after data compression using the computer. Film recording is also possible and Fig. 1 shows the record from a spread F structure showing five reflexion points, three distinct and two about 2.5° apart.

Early results indicate that almost all the spread F and spread sporadic E structures may be accounted for by reflexion

from a small number (up to seven at this time) of reflexion points, rather than scattering from substantial volumes. It has also been possible to measure the dispersion relationship of ionization irregularities. These results will be discussed in more detail elsewhere.

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Seasonal Anomaly in Ionospheric Radio Wave Absorption

THE temporal variation of the ionospheric absorption of radio waves in the 1.5 to 6 MHz range with the solar zenith angle (χ) is usually written in the form $\cos^n \chi$. Theoretically $n=1.5$ for absorption occurring in a Chapman layer, although such a theory cannot strictly be applied to the D region. On a diurnal basis, this variation is largely obeyed with values of n ranging from 0.5 to 1.0 and possessing a certain latitude dependence¹. There is, however, a delay in maximum absorption of approximately twenty minutes on local noon, due to the relaxation time of the D region².

On a seasonal basis, most investigators have tried to fit the absorption to such a $\cos^n \chi$ law, although in mid-latitudes this necessitates ignoring the four winter months, when the absorption is anomalously high. Moreover, the usual logarithmic plots of the remaining eight months' data generally show a considerable degree of scatter from the best straight line^{3,4}.

Beynon and Jones showed qualitatively⁵ that there existed an apparent delay in the time of maximum absorption in the seasonal variation of the monthly mean noon absorption for Freiburg (48.1° N), Slough (51.5° N) and Port Stanley (51.7° S). They also demonstrated that the collision frequency at 70 km, calculated from neutral atmosphere data, exhibited a superficially similar variation, including a comparable delay in attaining its maximum value after the time of maximum $\cos \chi$, and they suggested that the seasonal lag in absorption might primarily be caused by changes in the collision frequency. More recently, however, the seasonal variations of temperature and pressure have been shown⁶ to depend quite critically on altitude, with the result that the above explanation is no longer tenable without extensive modification.

During other absorption studies, we have examined this seasonal lag in further detail. Absorption measurements at mid and low-latitude stations have been analysed for all the available data for each station up to December 1970.

For a given month, there is a reasonably linear relationship between the monthly median values of absorption from year to year and their corresponding sunspot numbers (R_z). A mean value of absorption, corresponding to $R_z=100$, is obtained from this relationship by the least squares method.

We have fitted the seasonal variation of this absorption at the mid-latitude stations to a polynomial of degree five, the time of maximum absorption on the curve being found by scanning and application of the Newton-Raphson technique. The delay (ϕ) in this time after that of maximum $\cos \chi$ is plotted as a function of frequency in Fig. 1; ϕ is strongly dependent on frequency, with a sharp initial decrease to zero, followed by a more gradual increase at the higher frequencies. In addition, there is a close similarity between all three stations in both the form and magnitude of this dependence.

Of the two single frequency points in Fig. 1, one relates to Port Stanley (51.7° S), having a comparable value of ϕ relative

Fig. 1 Film record of raster display showing spread F echoes (the areas of brighter spots). The beam is swept $\pm 20^\circ$ off vertical in both the E-W (horizontal axis) and N-S (vertical axis) directions with an angular increment of 1.28° between consecutive beam positions. The N-S axis is tilted because of movement of film during recording.