INVESTIGATIONS OF THE
MOVEMENT AND
STRUCTURE OF
D-REGION
IONOSPHERIC
IRREGULARITIES

By

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(A paper presented in Journal of Geophysical Research, 84, 845, (1979))

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SUMMARY

Radiowaves (typically 2 to 50MHz i.e. HF and VHF radio bands) incident upon the ionosphere from below suffer weak partial reflection at altitudes between 50 and 100 km (the ionospheric D-region). These weak reflections are used to measure various parameters such as wind speeds and electron densities for the region. However, the mechanisms causing this scatter are not yet fully understood. The purpose of the work for this thesis was to obtain more information on the nature of these scatterers.

A wide variety of factors may be related to these scatterers, and so the first part of the first chapter is dedicated to a review of general properties of the D-region. This is followed by a more intensive review of previous investigations of D-region scatter characteristics.

Since turbulence may be important in relation to this scatter, the second chapter contains a review of turbulence. Some important formulae are presented, including some which are believed to be original.

Chapter III describes the equipment used for the investigations undertaken, and gives some preliminary observations, while Chapter IV discusses in detail many of the important general features of these scatterers. Chapter II can, in some ways, be considered as the most important chapter of the thesis. Observations were made near Adelaide, Australia (35°56'S, 138°30'E) and Townsville, Australia (19°40'S, 146°54'E), initially at frequencies close to 2MHz. Stratification of echoes was shown to occur. The first direct observations of the angular spectrum of the scatterers are also presented, and results agree with previous
indirect measurements. Scatter is generally quasi-isotropic above 80 to 85 km, but quite 'mirror-like' (Fresnel) below 75 to 80 km. The temporal variation of echo strength was also monitored, and at times extremely strong, short-lived "bursts" were observed. This was particularly so for heights below about 80 km, where power "bursts" up to 10 and 20 dB above the "normal" level could be seen. The observing equipment was fully calibrated, allowing absolute measurements of effective voltage reflection coefficients to be obtained.

Chapter IV also contains a review of VHF scatter observations by other authors, since VHF results complement HF results to some degree.

Investigations of the specularity of scatter by utilizing amplitude histograms are presented in Chapter V, and in particular the Rice distribution is extensively used. This may prove to be a controversial chapter, since it dismisses (with reasons) several investigations carried out by other authors. However, the author is confident of his results, particularly since they agree well with previous conclusions reached by studying the angular spectrum. It was found that scatter from below ≈ 80 km is quite specular, whilst scatter from ≈ 80 to 90 km appears to contain a mixture of specular and random quasi-isotropic scatter.

In all the observations, a knowledge of the background noise level is essential. For this reason, Chapter VI is dedicated to discussions of the determination of mean noise levels from observations of the signal. For cases in which both amplitude and phase are recorded this is quite simple, but the problem becomes somewhat more difficult when only amplitude is recorded. The presence of noise also distorts the auto-correlation function
if data is recorded as amplitude-only, and the form of this
distortion is discussed. It is believed that much of the theory
presented in Chapter VI is original work.

The use of equipment capable of recording both amplitude and
phase simultaneously also provided a major advance in the under-
standing of these scatterers. Such equipment was installed at
both the Townsville and Adelaide sites, and Chapter VII discusses
results obtained. It is shown that the fading times observed are
primarily related to beam-broadening, so these fading rates
cannot be used directly for determination of turbulence parameters.
However, some authors have attempted to make such measurements,
and some controversy may result from a few of the statements in
this chapter. It is also shown that observations taken with a
tilted beam produce wider power spectra than those taken with a
vertical beam. An explanation for this effect is presented, and
it is believed that this is the first time that this explanation
has been recognized. The explanation is related to 2-dimensional
turbulence. The effect is used to derive turbulence parameters
(eddy dissipation rate, eddy diffusion coefficient, outer scale),
and it is believed that the first such useful measurements at HF
are contained in this thesis. Estimates by other authors working
at HF are believed to have been made using erroneous assumptions,
and to have been adjusted to appear realistic by the manipulation
of unknown constants to compatible values.

A comparison of partial reflections was also made with
simultaneously recorded high resolution measurements of electron
density made during a rocket flight at Woomera, Australia
(30°45'S, 136°38'E), and the results are presented in Chapter VIII.
This comparison gave further insight into the nature of D-region scatter.

Chapter IX contains a more detailed search for mechanisms causing the scatter. The role of turbulence is discussed, and it is shown that this is unlikely to directly produce the observed scatter for heights below about 75 to 80 km. However, this does not rule out indirect turbulence effects. Above 80 to 85 km, turbulence is quite capable of producing a significant component of the observed scatter. The role of wind shears and gravity waves in producing these scatterers is also discussed. It appears that gravity waves may play an important role.

Towards the end of the work for this dissertation, facilities were installed at the Adelaide site to allow observations of the scatter at a frequency close to 6 MHz. The ability to observe on two frequencies simultaneously proved extremely useful, and comparisons of 2 and 6 MHz results are presented in Chapter X.

Although the exact nature of the scatterers is still not known, it is believed that this thesis has made some progress in understanding these scattering phenomena.