Stromlo, Australia, during the total solar eclipse of September 22, 1968, showed a phase delay of 3·0 μs (ref. 2). These observations seem to confirm Hildebrand's conclusion that there seems to be no distinguishable frequency dependence in the amount of phase advance.

The possibility of observing three VLF paths with two receiving stations was suggested by Dr F. H. Reder. This research was supported by the US Army Element Defense Research Office Latin America, Fundação de Amparo à Pesquisado Estado de São Paulo (FAPESP) and Conselho Nacional de Pesquisas (CNPq). We thank M. H. Paes de Barros, J. Teruo Ouchi and C. Monteiro for help.

RICARDO E. SCHAAL
ARACY M. MENDES
S. ANANTHAKRISHNAN
PIERRE KAUFMANN

Centre of Radio Astronomy and Astrophysics,
Mackenzie University,
São Paulo, Brazil.

Received May 11, 1970.

[1] Kaufmann, P., and Schaal, R. E., *J. Atmos. Terr. Phys.*, **30**, 469 (1968).
[2] Hoy, R. D., *J. Atmos Terr. Phys.*, **31**, 1027 (1969).

Comparison of 100 kHz Pulse Propagation during Two Solar Eclipses

IN July 1963 the path of a solar eclipse swept across the Aleutian Islands of Alaska. Low frequency (100 kHz) pulse transmissions of the US Coast Guard Alaskan Loran-C chain were observed in the one-hop sky-wave propagation mode for paths near regions of totality. This letter compares the data obtained during this eclipse[1,2] with results from the March 7 event.

In the 1963 data the phase of the ionospheric signal was retarded nearly in proportion to the increasing solar obscuration, indicating a maximum apparent reflexion height near maximum obscuration. Following the maximum obscuration, the phase advanced with an overshoot following the end of the eclipse (see Fig. 1). This pattern is similar to a change in ozone densities at heights above approximately 65 km calculated theoretically. The amplitude of the LF pulse signal increased rapidly near eclipse totality, and reached a maximim value 4 min after the time of totality. These changes are similar to calculated changes in the density of atomic oxygen for heights below about 65 km, except for the 4 min delay which was attributed to ionic composition changes that would take longer than 4 min if $[0] < 10^8$ atoms cm^{-3} during the eclipse.

During the March 1970 solar eclipse LF pulse observations were made over several paths of totality or near totality along the east coast of the United States, again using the Coast Guard Loran-C facilities. The midpoints of the paths were from 34° to 56° N latitude, and the path lengths were from 1,000 to 3,000 km. The behaviour during this eclipse was quite different from those observed in July 1963 (see Fig. 1 in which the March 1970 data (Dana, Indiana to Bermuda path) are typical of all paths). Rather rapid phase retardations were observed in the signals near the eclipse totality, with the maximum apparent height of reflexion occurring 5 min after totality. The amplitude change was small with the maximum signal level occurring slightly before totality. It should be pointed out that on March 7, 1970, a solar flare occurred less than 1 h before the eclipse started. This flare appreciably affected all the LF sky-wave signals and recovery was not fully achieved by the time the solar eclipse began as shown in Fig. 1. The flare may partly account for the amplitude maximum occurring before the time of maximum obscuration, but a complete explanation of this phenomenon is not easy.

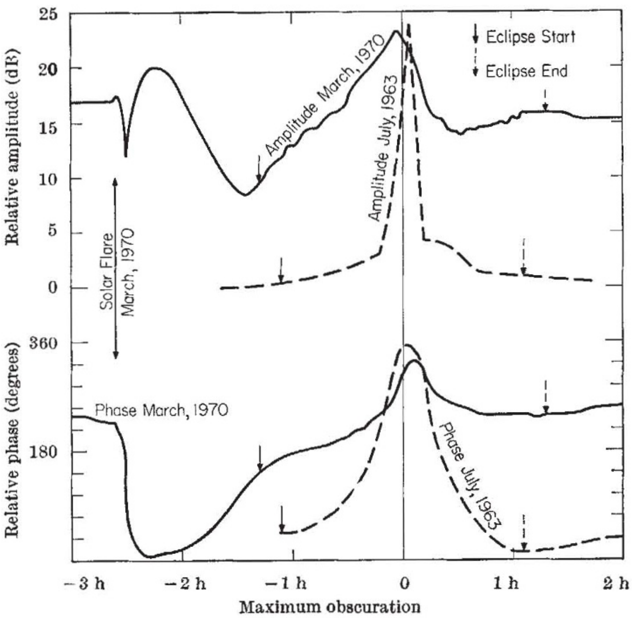

Fig. 1. Comparison of LF eclipse effects observed in July 1963 and in March 1970.

Aside from the problems produced by the solar flare preceding the eclipse, it is interesting to speculate on why the effects produced by the eclipse were so different in March 1970 and July 1963. The differences might have to do with the time in the solar cycle, different locations or path lengths for the measurements, or the season of the year. Both eclipses were near local noon, so the time of day should not be a factor. Routine LF sky-wave observations suggest that the propagation does not change appreciably with the solar cycle, apart from the effects of flares during solar maximum. The measurements in March 1970 covered several latitudes and several path lengths; if latitude or path length were a factor, the results from this eclipse should therefore have changed from path to path.

Seasonal changes in propagation do occur, however, and are similar in the United States and in the Aleutian Islands of Alaska. There is a lower reflexion height and greater ionospheric absorption in July than in March[3]. This could have to do with increased electron densities associated with increased production and concentrates of atomic oxygen during summer months, possibly by associative detachment of electrons from O_2^- by atomic oxygen. The daytime density profile of atomic oxygen would be expected to be lower in the summer than in March. Therefore the 5 min delay between the eclipse maximum and the phase peak observed in March could have been caused by the same mechanism that produced the delay of 4 min in the amplitude peak in the July measurements. If the apparent height of reflexion in March is determined by the density profile of atomic oxygen, few electrons would be produced by associative detachment by atomic oxygen at heights below this reflexion height because of rapidly decreasing atomic oxygen densities. Large amplitude changes, such as those observed in July, would not be expected to correlate with changes in the atomic oxygen density in this case.

ROBERT H. DOHERTY

Institute for Telecommunication Sciences,
ESSA Research Laboratories,
Boulder, Colorado.

Received May 4, 1970.

[1] Doherty, R. H., *J. Geophys. Res.*, **73**, 2429 (1968).
[2] Doherty, R. H., *J. Atmos. Terr. Phys.* (in the press).
[3] Doherty, R. H., *Radio Science* (*New Series*), **2**, 645 (1967).