SHORT COMMUNICATIONS

ANOMALOUS VHF TRANS-EQUATORIAL IONOSPHERIC PROPAGATION RECORDED AT TOWNSVILLE*

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Since Ferrell (1951) first reported anomalous VHF propagation in equatorial regions, a number of workers have observed the phenomenon during the early afternoon and evening hours, especially the latter. Backscatter experiments in the neighbourhood of the Virgin Islands were carried out by Villard, Stein, and Yeh (1957) employing fixed-frequency radar sounders located at St. Croix and by Dueno (1960) from Mayagüez. Villard, Stein, and Yeh observed backscatter signals, at frequencies up to 46·2 Mc/s, corresponding to slant ranges up to 8000 km between 1500 and 2100 hr local time. These results were attributed to successive reflections from a tilted F layer without intermediate ground reflections (^nF propagation). Dueno investigated the long-range trans-equatorial (LRTE) echoes at frequencies up to 49·68 Mc/s over a two-year period. He found a marked seasonal variation in the occurrence, the maxima occurring during the equinoctial periods. Low angle of arrival of the signals was deduced.

Similar effects have been observed in the Far East but to a much greater extent. It is now well established that during the September equinox in the Far East a considerable enhancement in evening signals at 50 Mc/s persists for periods of up to 5 hr with a gradual fading away. The phenomenon, which has come to be known as "the Far Eastern anomaly", occurs 100 times more frequently in the eastern than it does in the western hemisphere.

Smith and Finney (1960) attributed propagation of this kind to an F-region scatter mechanism. Subsequently forward-scatter measurements by Finney *et al.* (1961), conducted through circuits in the neighbourhood of the Phillipines, definitely established the F-region origin of the Far Eastern anomaly.

In the present note observations are described which show that trans-equatorial signals are propagated over much longer Far Eastern paths than have been reported hitherto. Since before the IGY, amateurs in the vicinity of Townsville (latitude 19·25°S., longitude 146·75°E., and geomagnetic latitude 28·4°S.) have observed pronounced LRTE signals during the equinoctial periods from various sources in the neighbourhood of Korea and Japan.

During August-September 1960 one of us (R.J.C.) observed signals in the range 49–56 Mc/s at the Ionospheric Prediction Station at Townsville. A fringe-area TV receiver coupled to a pair of stacked 5-element Yagi antennae was operated

* Manuscript received September 20, 1962.

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daily from approximately 0900 to 2400 hr local time. The occurrence of LRTE signals over ranges up to 8000 km was noted. The signals originated from such sources as television transmitters in Vladivostock and Honolulu, FM transmitters in Korea, and amateur operators in Russia and Japan. Observations were confined to the equinoctial period, since it is generally established that no signals are received in this area during the solstitial periods. Times of occurrence of the signals are shown in Figure 1. These values are necessarily approximate, since continuous visual

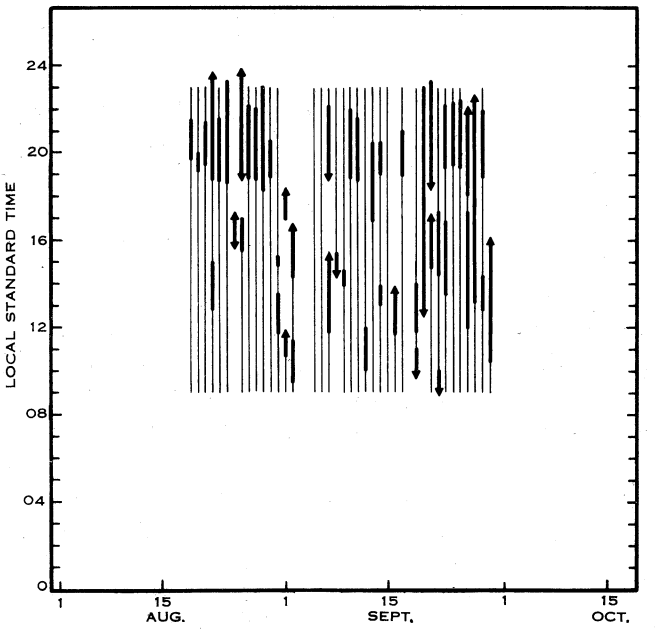

Fig. 1.—Times of occurrence of long-range trans-equatorial signals, Spring 1960 (values obtained by visual monitoring of a television receiver).

monitoring obviously could not be sustained for the entire daily period. The diurnal variation of the LRTE observations shows a small peak centred about 1400 hr and another peak about twice as high at 2000 hr. The latter presumably corresponds with the Far Eastern anomaly.

To obtain more precise information an experiment was established to record continuously LRTE signals observed at one particular frequency and arriving over a limited range of azimuths. For these measurements a Hallicrafters communication receiver Type S36 was coupled to a log-periodic antenna having a gain of approximately 6 dB compared with an isotropic dipole; the receiver output was fed to a panoramic adapter and recording camera. The antenna was directed towards Korea, on a great-circle bearing of 331°. The bandwidth of the panoramic adapter was adjusted to cover a frequency range of 400 kc/s. Calibration of the equipment was carried out by means of a signal generator and precision frequency source which was accurate to well within $\pm 0{\cdot}01$ Mc/s. This leads to an overall accuracy of at least $0{\cdot}05$ Mc/s

in the autumn 1962 records. Some uncertainty in absolute frequency values (about 0·3 Mc/s) exists in the case of the spring 1961 results due to lack of adequate calibration and subsequent equipment adjustment. The signals were identified for the most part from program material and in some cases station call signs. For

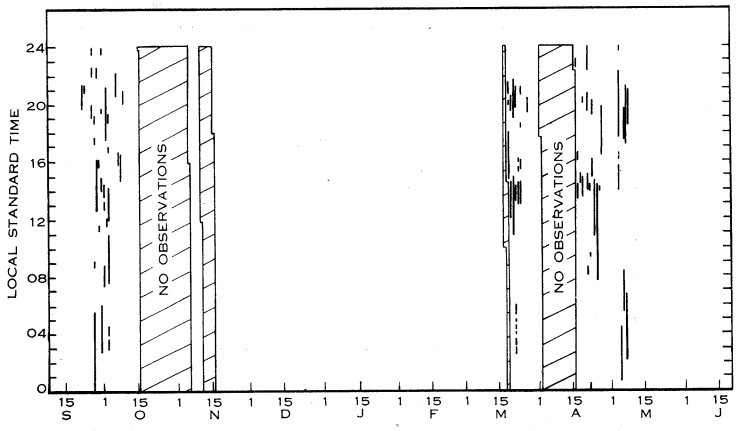

Fig. 2.—Times of occurrence of long-range trans-equatorial signals, September 1961 to June 1962 (values recorded continuously during the period).

example, F.M. transmissions from Korea have been identified at frequencies of 48·0, 48·3, and 48·6 Mc/s. Although it has not been possible to identify all signals reported in the present work, identification of a Korean F.M. source has been made from time to time by simultaneous audio monitoring. The results of continuous

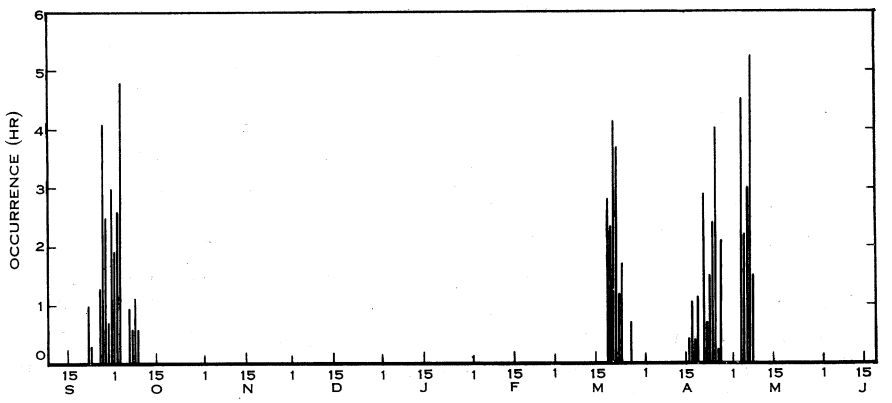

Fig. 3.—Aggregate long-range trans-equatorial signals, September 1961 to June 1962.

observations at 48·0 Mc/s over the period September 1961 to June 1962 are shown in Figure 2.

The seasonal variation of the LRTE signals recorded in Figure 2 is illustrated in Figure 3 where the daily aggregates are shown. The complete absence of any recep-

tion during the period November 1961 to March 1962 is characteristic of LRTE reception in the Townsville region. The periods during which no records were made at the latter end of the vernal equinox 1961 probably lie, at least partly, in this quiescient period. On the other hand the period of no observations during April 1962 may well have resulted in the loss of some recordable signals.

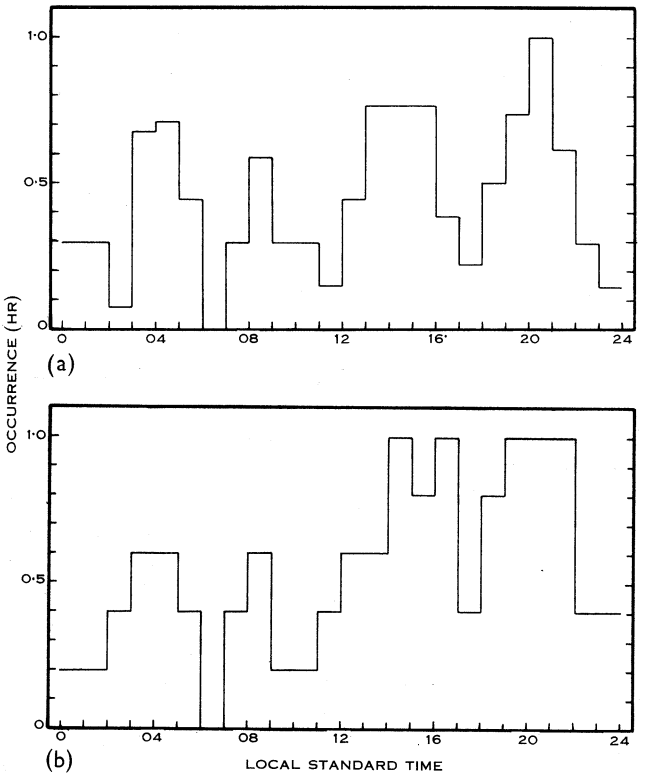

Fig. 4.—Diurnal occurrences of long-range trans-equatorial signals, spring equinox 1961. (*a*) Based on aggregate times of occurrence, (*b*) based on number of occurrences.

Diurnal variations for the two equinoctial periods appear in Figures 4 and 5. Figure 4(*a*) represents, for each hour of the day, the total time that signals were recorded during the particular hour throughout the spring equinox. Figure 4(*b*) is a plot of the number of days throughout the spring season on which signals were recorded during the respective hourly intervals of the day. Similar histograms for the autumn equinox 1962 appear in Figure 5. The plots have been normalized to their respective maxima.

The two morning maxima more or less evident in all four histograms reveal phenomena which do not appear to have been reported previously. The absence of such a morning maximum in the preliminary visual observations shown in Figure 1 is puzzling but may be accounted for by the uncertain continuity of these observations.

The present experiment belongs to the "forward-scatter" class, with the transmitters and receiver at opposite ends of the circuit. All previously reported LRTE experiments with path lengths near 8000 km have been backscatter experiments. Dueno points out that backscatter experiments tend to produce results "on the pessimistic side". Perhaps it is for this reason that the early morning LRTE signals have not previously been recorded in the Western Hemisphere. Some of the

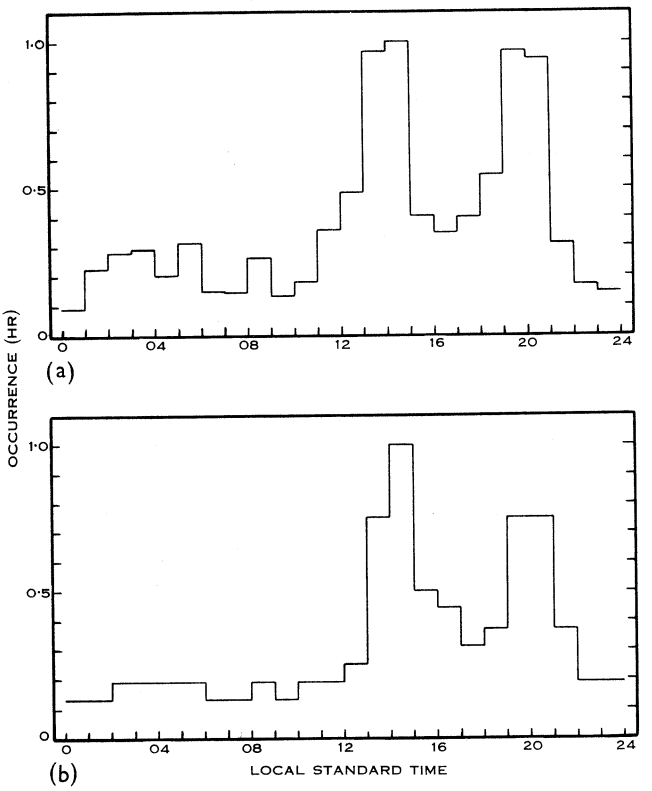

Fig. 5.—Diurnal occurrences of long-range trans-equatorial signals, autumn equinox 1962. (*a*) Based on aggregate times of occurrence, (*b*) based on number of occurrences.

amateurs in the Townsville area have observed signals at least until 0200 hr. Lack of further evidence from this source is no doubt accounted for by the fact that amateurs do not usually operate VHF much after midnight.

No one mechanism can account for the four maxima shown in Figures 4 and 5. Only in the case of the evening maximum does there appear to be some possibility of interpretation in the light of previously reported pulse experiments. The evening anomaly most likely results from *F*-region scatter, as suggested by Smith and Finney (1960) and Finney *et al* (1961). The alternative seems to be the ^{n}F type propagation, as suggested by Villard, Stein, and Yeh, and this is the mechanism which appears to be ruled out for short paths of the order of 1500 km, as for example

in the investigation of Smith and Finney in their Far Eastern work to the north of the magnetic equator.

The authors wish to record their appreciation to Professor H. C. Webster and Dr. J. A. Thomas of the Physics Department, University of Queensland, for their assistance with equipment and valuable discussion. We also thank the Director of the Ionospheric Prediction Station at Townsville for providing helpful facilities.

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