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Further studies of long range trans-equatorial v.h.f. radio signals at Townsville

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Abstract—The occurrence of long range trans-equatorial signals received at Townsville is shown to follow definite seasonal and diurnal variations. Afternoon signals are heard regularly during the equinoctial months, while evening signals show a marked decrease in occurrence as the sun-spot cycle progresses toward minimum. Frequency–signal strength relationships based on the observations are also discussed.

1. INTRODUCTION

CONTINUOUS monitoring of long-range trans-equatorial v.h.f. radio signals (LRTE) has been carrried out at Townsville (latitude 19·25°S, longitude 146·7°E and geomag. lat. 28·4°S) since September 1961. Observations at the single frequency 48·0 Mc/s have already been reported (CARMAN *et al.*, 1963) for the period September 1961 to June 1962. In the present paper, an analysis is made of LRTE signals in the frequency range 44–48 Mc/s received at Townsville from transmitters in Korea, over a surface path length of about 6,600 km. These results involve propagation over a much longer path—Korea to Townsville (6,600 km)—than has been reported by other workers in the Far East. A comparison of this trans-equatorial path with the path of other workers both in this region and in the Western Hemisphere is given in Fig. 1.

SMITH and FINNEY (1960) investigated the propagation of 50 Mc/s signals over the 1280 km path from Poro Point in the Philippines to Okinawa during 1957–58. More recently MIYA *et al.* (1961) conducted forward scatter experiments over the Okinawa–Tokyo (1480 km) and Poro Point–Toyko (2850 km) paths. In both cases the propagation was attributed to an F-layer scatter mechanism. All other long-range trans-equatorial observations have been carried out in the American Hemisphere. Among these are the backscatter experiments of VILLARD *et al.* (1957) in the Virgin Islands, (over paths ranging from 5500 to 11,000 km to the south) who often observed signals between 1500 and 2100 hours L.T. during August–September 1956. A good proportion of these paths are bisected by the geomagnetic equator, and correspond closely in this respect to the path from Seoul to Townsville. VILLARD *et al.* attributed this propagation to successive reflections from tilts in the F-layer without intermediate ground reflections (^nF-propagation). Detailed analysis of the proposed propagation was subsequently reported by STEIN (1958). Seasonal variation was first investigated by DUENO (1960). He found a well-defined maximum occurred in the equinoctial months during a two-year period by observing echoes at 40 and 50 Mc/s originating from a backscatter receiver located at Mayagüez.

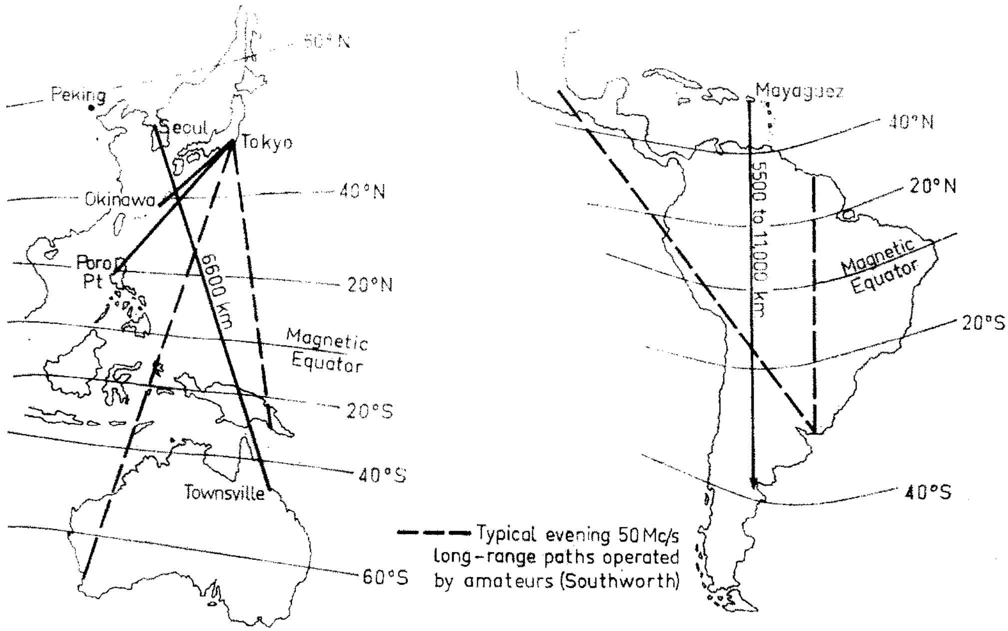

Fig. 1. The map shows typical LRTE paths in the Australian and American zones Note that Seoul and Mayagüez both have dip angles of approximately 52°N.

2. Experimental Procedure

In the absence of suitable continuous or pulsed transmitters, use was made of the f.m. link transmissions of the Korean Broadcasting Service (K.B.S.) in Seoul, Korea. The present authors are not in possession of detailed information regarding the links themselves. However it is known that they are comparatively low powered v.h.f. transmitters used to relay programme material to various broadcast and shortwave transmitters near Seoul. The source was identified by the station call signs, occasional English-language programmes, and further information recently made available through the courtesy of the U.N. Command. Table 1 shows the frequencies of the verified f.m. links used by K.B.S. for relaying local and overseas programmes. K.B.S. transmissions have been received in Townsville on several other unverified frequencies including 44·5 Mc/s and 45·7 Mc/s. Transmissions have also been received from Radio Peking, China, on 45·2 Mc/s, during the afternoon in the early part of the equinoctial season. However these transmissions appear to

Table 1. Frequency of Korean Broadcasting Service f.m. links verified by private communication

Local	Overseas
44·3 Mc/s	45·5 Mc/s
44·9 Mc/s	48·0 Mc/s
46·3 Mc/s	

operate only from 1300 to 1500 hours L.T. and were received only when the Korean circuit was open simultaneously.

The equipment used during the first four equinoxes (September 1961 to May 1963) consisted of a standard Hallicrafters v.h.f. communications receiver S36 in conjunction with a Panoramic Pan-adaptor (to facilitate monitoring) and an oscilloscope equipped for film recording. The antenna was a wide band log-periodic

Table 2. List of frequencies monitored continuously together with equipment used

	Spring 1961, Autumn 1962, Spring 1962 and Autumn 1963		Spring 1963
Receiver	Hallicrafters S36 with 50 Ω/300 Ω Matching Pad		Modified Hallicrafters 300 Ω input
Antenna	Log-Periodic (50 Ω Impedance)		Pair of 4 element Yagis (300 Ω)
Frequency range of receiver	46·0 Mc/s upward		43·5 Mc/s to 52·0 Mc/s
Frequency monitored continuously	48·0 Mc/s 22 September 1961 to 17 October 1962	46·3 Mc/s 12 March 1963 to 9 May 1963	44·5 Mc/s* 22 September 1963 to 20 November 1963
Approximate thresh-hold signal strength (dB rel. to 1 μV)	+10 dB	+10 dB	−6 dB

* Unconfirmed value

type, directed towards Seoul on a great circle bearing of 331°. This receiver was rebuilt during the winter of 1963 to improve sensitivity and signal-to-noise ratio. Also the frequency range was restricted to cover the band from 43·5 Mc/s to 52·0 Mc/s. To increase gain the log-periodic antenna was replaced by a coupled pair of 4-element Yagis.

The foregoing simple experimental arrangement restricted continuous monitoring to one frequency only. Table 2 shows the actual frequencies monitored continuously and shows a comparison of the equipment used during the respective seasons. All times are Australian Eastern Standard Time, (i.e. G.M.T. + 10).

3. Experimental Results

The most significant features of the data compiled over the five equinoctial seasons are shown by Figs. 2–4. In Fig. 2 each histogram shows the total percentage of daily occurrences of Korean LRTE signals during each hour of the day for a particular season. Each histogram is normalised to its maximum, which in all cases is the afternoon peak of occurrence. The Spring 1962 histogram is incomplete due to faults in the recording equipment; results are given only for the time an observer was in attendance. The data near the 1963 Autumn and Spring peaks of Fig. 2 is

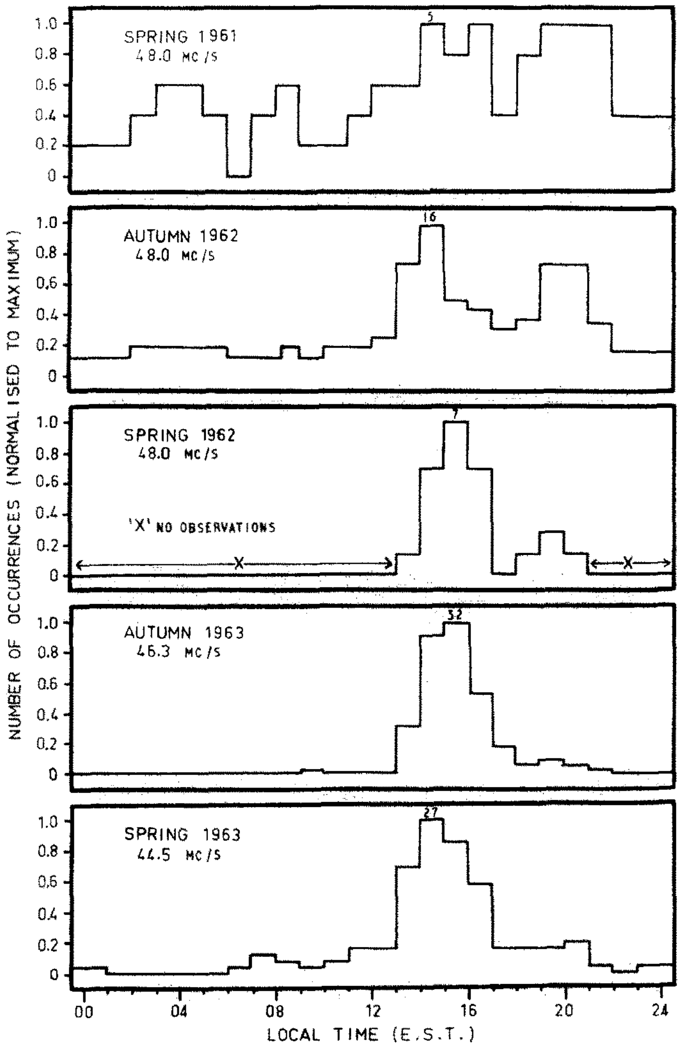

Fig. 2. Diurnal occurrences of Korean LRTE from Spring 1961 to Spring 1963 normalized to maximum. Numbers on peaks indicate relative sizes of maxima.

compared with similar data for 48·0 Mc/s in Fig. 3. The number above each afternoon peak in Fig. 2 represents the actual number of occurrences at the respective times. Figure 4 shows the aggregate total of the number of hours each day during which signals were received from Seoul on the frequencies specified. Days on which no data was obtained are indicated by crosses. The values plotted in Fig. 4 are signal strengths in dB relative to an input signal of 1 μV (50 Ω) for three days in March 1963. This latter data will be referred in the next Section.

4. Discussion of the Results

Table 2 shows that the frequency chosen for continuous monitoring was reduced following Spring 1962. This change resulted from the observation during the previous three seasons that the occurrence and duration of the 48·0 Mc/s signals were progressively waning, suggesting that the m.u.f. was decreasing as sun-spot minimum was approached. This fact could be anticipated, since as Southworth (1960) notes, radio amateurs who persistently monitored LRTE at 50 Mc/s during the

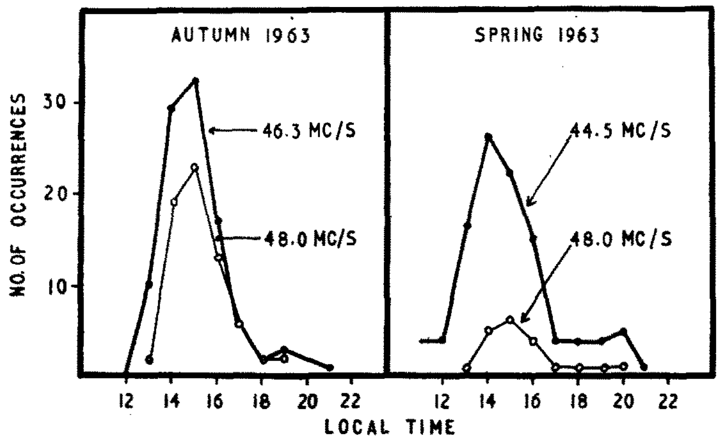

Fig. 3. Comparison of actual number of occurrences of LRTE during (a) Autumn 1963 and (b) Spring 1963 at the frequencies indicated.

previous sun-spot minimum (1951–54) observed little or no trans-equatorial propagation. Furthermore, Dueno (1960) found that there are many more LRTE echoes on 40 Mc/s than on 50 Mc/s. Further striking evidence of the progressive waning of the 48·0 Mc/s signals can be seen from Fig. 3 where it is noted that the Spring 1963 results were obtained with the receiver at increased sensitivity and where the close correlation between the diurnal variation in the occurrence of signals at the respective frequencies is also shown.

Of particular interest is the gradual reduction, and almost complete disappearance, of evening signals. Reference to Fig. 1 of Carman *et al.* (1963) shows that in Spring 1960, evening LRTE signals occurred about twice as often as afternoon signals. However, in Spring 1961 and Autumn 1962, the numbers of occurrences are about equal, while in Autumn 1963 the ratio of afternoon to evening occurrence is about 10:1. In Spring 1963, even with a more sensitive receiver, the ratio is still greater than 5:1.

The present evening (1800–2100) results are in agreement with Southworth's (1960) report that night-time LRTE was most prevalent during the I.G.Y. and almost completely absent during the time of sun-spot minimum. On the other hand the present series of experiments suggest the occurrence of afternoon LRTE (1300–1600) might not be closely dependent on the sun-spot cycle. Thus two different modes might well be involved in the propagation of afternoon and night-time signals. Villard *et al.* (1957) have shown that two F-layer tilts are encountered regularly in equatorial regions; one occurs almost daily at approximately 1900 over the geomagnetic equator and another around noon in the vicinity of the subsolar point. Due to the direction of the Seoul–Townsville path this noon tilt would occur at about 1300 L.T. corresponding roughly to the normal opening of the afternoon signals. Villard *et al.* also suggests the noon tilt could produce a ^3F-mode of

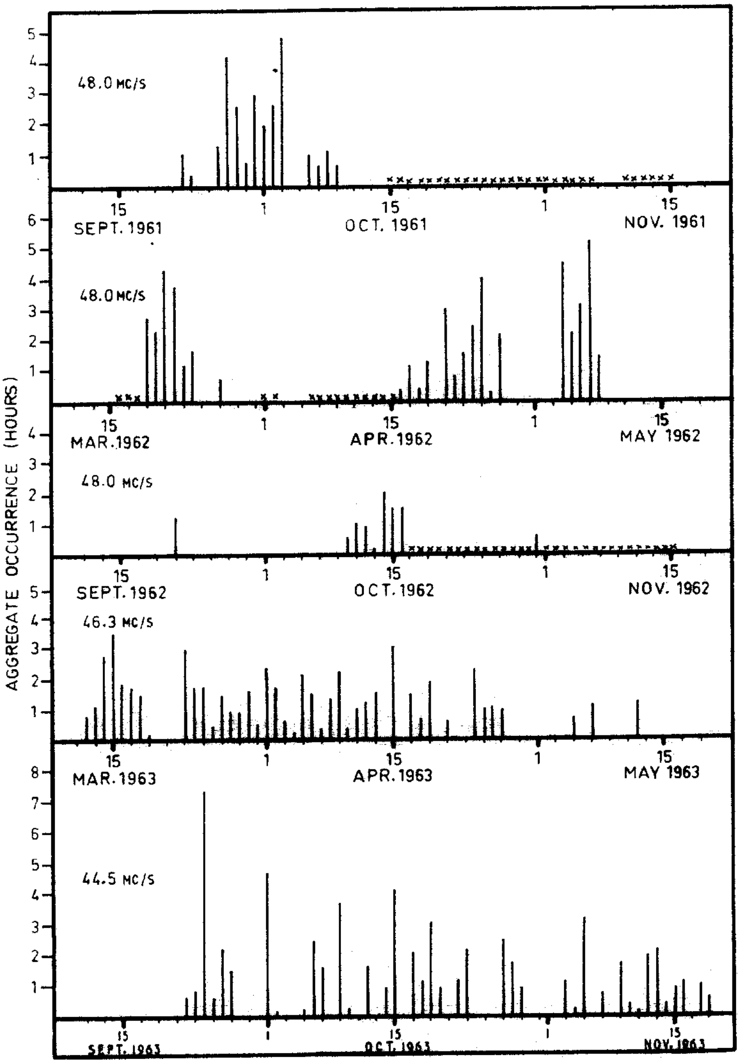

Fig. 4. Aggregate period of occurrence of Korean LRTE from Spring 1961 to Spring 1963. Dots indicate days on which no data was available.

propagation rather than the ^2F-mode assumed to account for the evening propagation. Only a rough indication of the influence of frequency is possible from the present results. Fig. 5(a) is typical of the the frequency–signal strength relationship occurring most often. Here the respective openings at both frequencies are more or less "in-phase". But deviations from this typical pattern occur. For example Fig. 5(b) for 30 March 1963 shows three openings on 46·3 Mc/s and only one on 48·0 Mc/s while

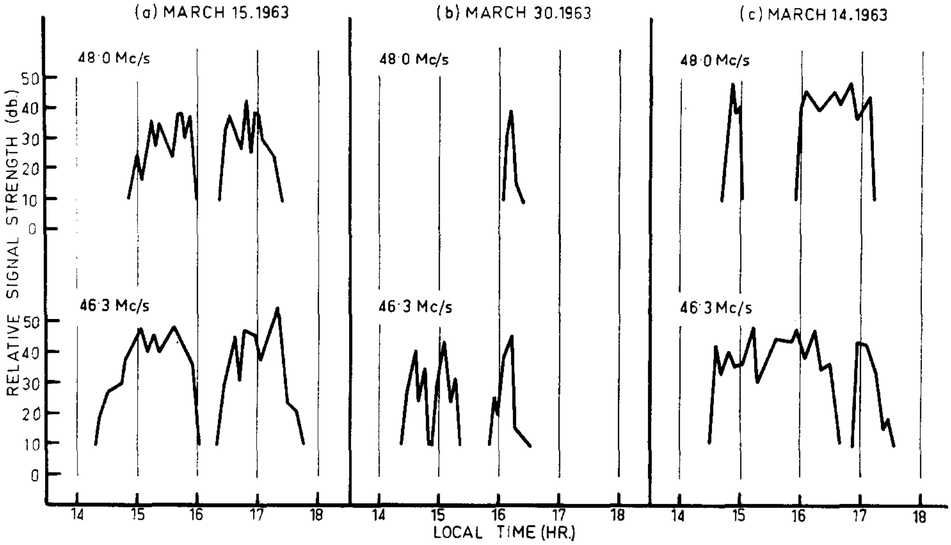

Fig. 5. Strength of Korean LRTE signals received at two frequencies at Townsville during Autumn 1963.

(a) 15th March, 1963 (typical example of behaviour for this equinox)
(b) 30th March, 1963
(c) 14th March, 1963

Fig. 5(c) for 14 March 1963 shows two openings on each frequency. There appears to be no marked tendency for signals at the two frequencies to occur "in-phase" in the latter case.

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