INVESTIGATIONS OF LONG-DISTANCE VHF/UHF AMATEUR CONTACTS ACROSS THE GEOMAGNETIC EQUATOR

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On the evening of Octover 29 1977 YV5ZZ in Venezuela contacted LU1DUA in Argentina on 144 MHz, spanning a distance of 5044 km. This appears to be the first reported distance of long-distance 144 MHz propagation crossing the geomagnetic equator.

Subsequently, VK8GB in Darwin exchanged reports on 144 MHz with JH6TEW on Kyushu in Japan on February 24 1978. On April 10 1978 ZE2JV in Rhodesia worked 5B4WR on Cyprus on 144 MHz.

Since that time, the number of reported contacts on the 144 MHz band, with signals crossing the geomagnetic equator, has climbed into the thousands. There has been much speculation about the mode of propagation — whether it is sporadic-E, ionospheric scatter, field-aligned ionospheric scatter (FAI), transequatorial propagation etc.

The writer has investigated the diurnal, seasonal and signal characteristics of contacts reported by VK8GB during 1978. It is suggested that the reports are consistent with the known characteristics of Class II (evening-type) transequatorial propagation.

Recent ionospheric research has produced a number of tentative models explaining the mechanism of this type of propagation. This will be only briefly discussed as another paper on the subject will cover it in detail.

THE AMATEUR MAGAZINES have been reporting instances of contacts and signals observed over long-distance paths crossing the geomagnetic equator on 144 and 432 MHz, with increasing frequency, since late 1977.

These spectacular events, resulting in the shattering of the world terrestrial DX record on 144 MHz, have been the subject of intense interest amongst the VHF fraternity world wide, and a deal of speculation as to the mode of propagation supporting the signals.

A recent article in QST titled: "A Newly Discovered Mode of VHF Propagation", by Joseph Reisert W1JR and Gene Pfeffer K0JHH, excited my interest as it detailed a number of these interesting propagation events and offered an hypothesis in explanation. Having worked in transequatorial propagation research during the early part of this decade, I retain a very active interest in propagation and ionospheric matters.

Reisert and Pfeffer's article, in the October 1978 issue of QST, was therefore, of particular interest to me. However, I wish to take issue with their proposed mode of propagation. I propose to show that the recent 144 MHz openings **do not** exhibit "... many characteristics which were previously unobserved or unexplained." The propagation mode is actually **Class II, or evening-type, transequatorial propagation** (TEP) — often confusingly referred to as 'TE scatter' in US-sourced publications.

Background

Amateur contacts on the 50 MHz band over distances of 4000 to 10 000 km spanning the geomagnetic equator have been reported consistently since 1947. A variety of research projects carried out between the early 1950s and first half of this decade has seen greatly increased understanding of what is termed 'Transequatorial Propagation', or TEP, that supports signals over considerable distances at frequencies well into the VHF spectrum. This research has brought to light two modes of TEP — Class I, or afternoon-type, and Class II, or evening-type. They are so designated as Class I has a predominant diurnal occurrence between 1400 and 1900 local mean time (LMT), whereas Class II has a peak occurrence around 2000 to 2300 hours LMT.

The upper frequency limit for Class I TEP seems to be around 60-70 MHz, hence the frequently reported afternoon contacts on the six metre band, along with reception of television and other signals in the 40-60 MHz region from areas across the opposite side of the geomagnetic equator. Class I TEP is sometimes known to reappear after local sunset, occasionally existing simultaneously with Class II.

No upper frequency limit has been proposed for Class II transequatorial propagation. The highest frequency observed until the mid-1970s was 102 MHz.

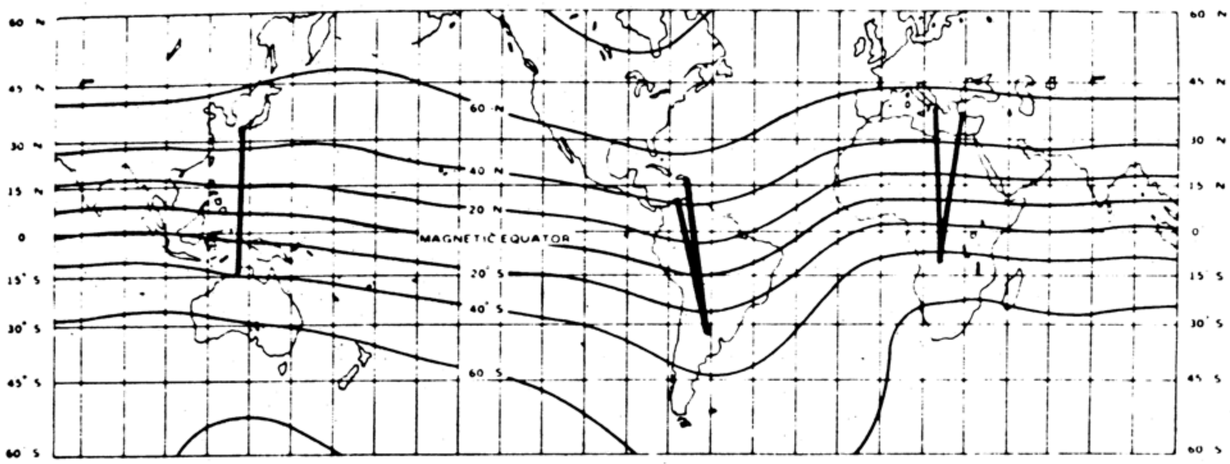


Figure 1. **The primary paths over which transequatorial contacts on 144 MHz have occurred. Left to right: the Australasian region, the American region and the African region.**

A 1 kW beacon, located in Darwin, Australia, was monitored in Yamagawa in southern Japan, from the mid-1960s to 1974, as part of a cooperative propagation study between Australian and Japanese ionospheric research establishments.

The references listed at the end of this article are recommended.

Class II TEP

Before examining the reports of the spectacular 144 MHz contacts, let's take a look at the characteristics of evening-type TEP and the known criteria necessary to allow propagation of signals via Class II TEP.

Evening-type TEP has the following general characteristics:

(a) A peak diurnal occurrence around 2000-2300 hours LMT, (measured at the point where the path crosses the geomagnetic equator).
(b) A characteristic 'flutter' fade, at rates up to 15 Hz, often deep, and a doppler spread up to 15 Hz (giving rise to comments such as "sounds like moonbounce signals").
(c) Path lengths are generally about 3000-6000 km, path terminals (i.e: station location) are generally situated between geomagnetic latitudes of 10° and 20° north and south of the geomagnetic equator.
(d) Strong equinoctial dependance — openings occur most often around the equinoxes, although they can occur at other times under suitable conditions.
(e) High signal strengths are often observed, occasionally above values equal to free-space path signals for the same distance, varying from 70 dB to 20 dB below free-space figures in general.
(f) Paths generally cross the geomagnetic equator at near normalcy — i.e: a small range of angles around 90° to the geomagnetic equator. Paths having an obliquity with the geomagnetic equator of more than 15° experience considerably fewer occurrences than those at near normalcy — particularly at the higher frequencies.

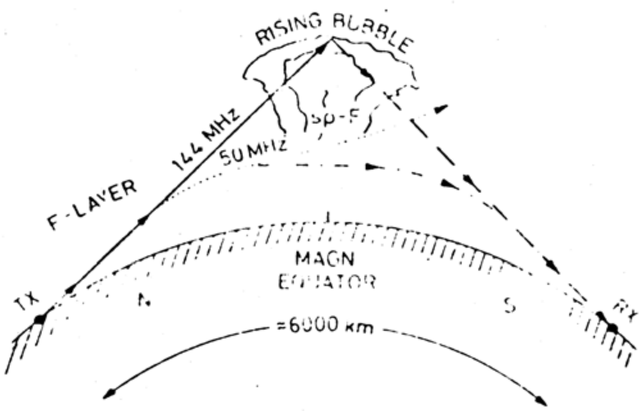


Figure 2. **The propagation mode proposed by Rottger involves forward scattering from irregularities occurring in connection with high-rising "plasma bubbles" in the equatorial ionosphere discovered by Woodman and La Hoz (Reference 1).**

Models proposed

Following publication of the research findings of R.F. Woodman and C. La Hoz (Ref. 2), who used a 50 MHz radar to study the equatorial ionosphere above Jicamarca in Peru, a number of researchers have attempted to explain the propagation mechanism supporting this remarkable form of propagation.

Prior to 1978, the following four models were proposed:

1. Refraction from the F-layer.
2. Scatter from 'irregularities' (small, dense 'patches' of ionisation) in the F-layer.
3. Double scattering from two patches in the F-layer either side of the geomagnetic equator.
4. Guidance of signals by irregularities aligned with the Earth's magnetic field.

All of these proposed mechanisms suffered from varying drawbacks. The first, refraction from the F-layer, proved to be impossible at the frequencies involved (greater than 50 MHz) from the known characteristics of the equatorial ionosphere.

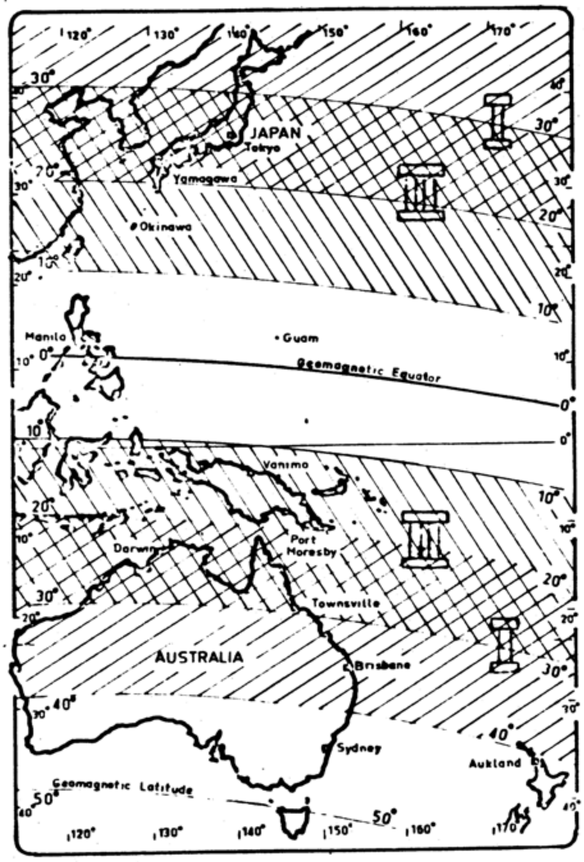


Figure 3. **Australasian region showing the general terminal zones for Class 1 TEP (20° to 40° geomagnetic latitude) and Class II TEP (10° to 30° geomagnetic latitude).**

An ensemble of irregularities in the F-layer cannot return sufficient power to the opposite side of the geomagnetic equator unless shaped so that the signal is focussed, providing coherent addition of the signal over many paths. This was shown to be highly unlikely and certainly did not match up with observations. Scratch model 2.

Double scattering from two patches of irregularities either side of the geomagnetic equator, without an intermediate ground reflection, was eventually considered suspect as it proved difficult to estimate path loss reasonably, although the geometry of the situation fitted the observations. There were a number of other difficulties.

Guidance of signals by field-aligned irregularities received the most attention as it offered the best 'match' to most observations, although some conflicts proved difficult to resolve.

The article in QST by Joe Reisert and Gene Pfeffer attempted to explain 144 MHz propagation over transequatorial paths in terms of scattering from field-aligned irregularities. This theory is an extension of model 2 and suffers from the same limitations, although the observational material is excellent.

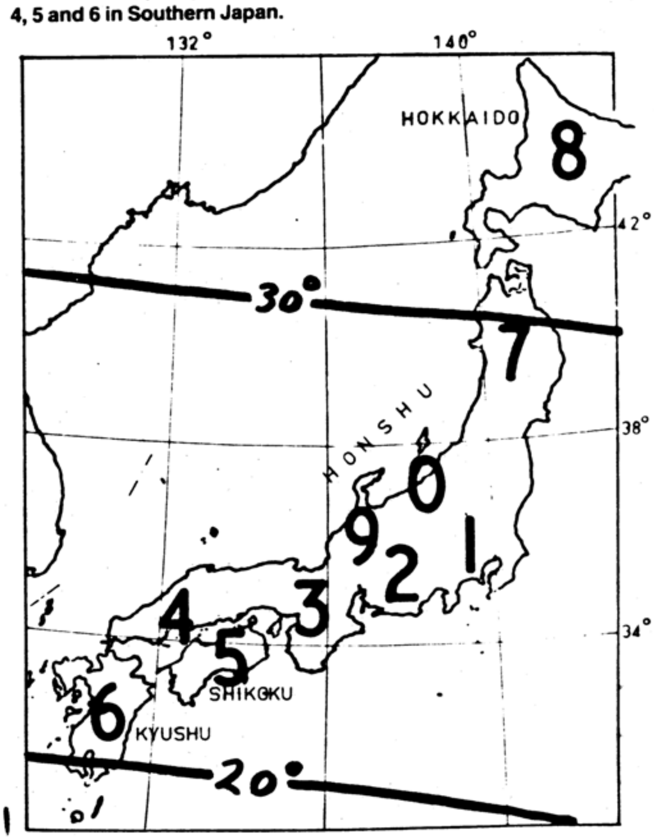
An article by Jorgen Rottger (DJ3KR) in the December 1978 issue of Radio Communication ascribed 144 MHz TEP to forward scattering from irregularities occurring in connection with high-rising "plasma bubbles" in the equatorial ionosphere. These plasma bubbles were described by Woodman

Roger Harrison, VK2ZTB, presented both this paper and M.L. Heron's paper as the latter could not attend.

and La Hoz and consist of elongated tubes or bubbles of depleted ionisation that rise through the equatorial ionosphere after local sunset and travel from west to east. Small, dense irregularities are associated with the 'walls' of these bubbles.

This theory proved to be on the right track but scattering could not account for the received signal powers observed. Also, the proposed mechanism requires transmitted and received angles of elevation not found in observations (although more observations are necessary). Rottger's theory does explain quite a number of the observed signal characteristics. The periodicity of generation and movement of the bubbles accords quite well with results of long-term fading observations detailed in Rottger's paper.

Figure 4. **Japan, showing call areas and geomagnetic latitude. VK8GB works stations on 144 MHz predominantly from areas 4, 5 and 6, very occasionally area 3. Darwin is about 22° South geomagnetic latitude, pretty well at the geomagnetic conjugate of call areas 4, 5 and 6 in Southern Japan.**



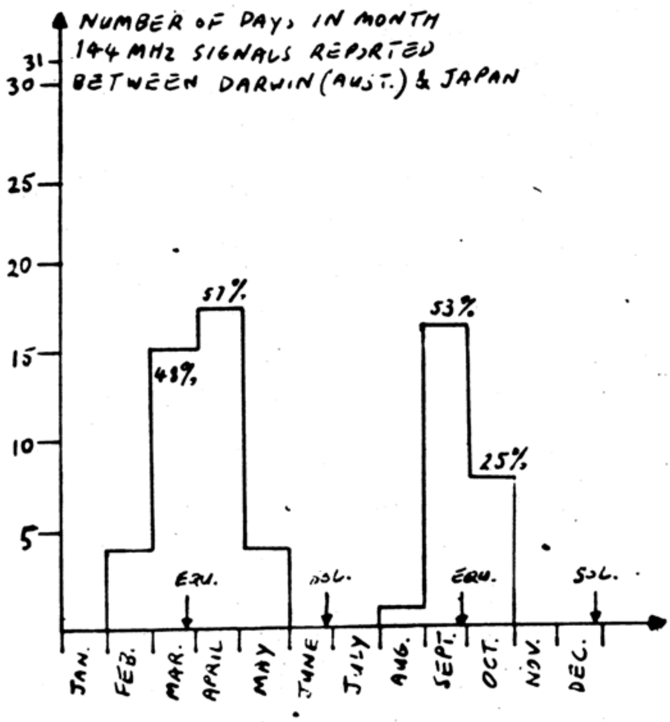


Figure 5. **Seasonal occurrence rate of 144 MHz propagation between Darwin and Japan, derived from the logs of VK8GB, during 1978 expressed as a percentage of days in the month signals were observed. Note the strong equinoctial dependence.**

The Japan-Australia circuit, analysis of reports from VK8GB.

I have completed an analysis of the 144 MHz Australia-Japan contacts for 1978 reported by Graham VK8GB and Brian VK8VV. The reports were taken from the column "VHF-UHF An Expanding World" conducted by Eric Jamison VK5LP in the WIA's journal 'Amateur Radio'.

It is a tribute to the meticulous, detailed and accurate accounts that Eric gives in his column that I have been able to do a reasonable analysis and reduction of the data presented. It's a pity more column writers in this field couldn't follow his lead.

Several graphs are reproduced here showing occurrence rates over the year and diurnal occurrence times reported.

Quite clearly, from the graphs of occurrence rates, these contacts between Australia and Japan (Darwin to southern Japan) have a strong equinoctial character. The peaks of the monthly occurrence rates 'lean' towards the mid-year solstice (June 21), an interesting phenomena.

The graph of diurnal occurrence rates indicates a clear peak between 2000 and 2200 hours local mean time. The longest durations of openings are associated with the week around the equinoxes — again showing a tendency towards the mid-year solstice.

Work by MacNamara (see References) shows that range-spreading on ionograms from Vanimo (PNG) for this circuit, coincident with propagation observations, is a *necessary* but not sufficient condition for the existence of Class II TEP.

An examination of Table 1 shows that, for the reported contacts, *this condition is met* with the exception of a few isolated instances.

As Vanimo is somewhat to the east of the Japan-Darwin path, short-lived disturbances in the F-layer, associated with Class II TEP, may not be seen on Vanimo ionograms although propagation did occur. Nevertheless, the dependance of the reports on this criteria is very strong.

A statistical analysis has not been attempted as it is felt to be unnecessary under the circumstances.

Reisert and Pfeffer report some angle-of-arrival measurements carried out by YV5ZZ and KV4FZ that indicated signal received on 144 MHz (KV4FZ-LU3AAT) and 432 MHz peaked at elevations of 8-10°. This is consistent criteria for Class II TEP presented by both Nielson and MacNamara.

Also, reported signal strengths are very strong under "good" conditions, well over strength nine, many occasions averaging strength seven or more. Even though these are 'guesstimates' a reasonable estimate of signal levels can be made, going by modern receiver performance measurements.

A signal of 50 uV at the antenna of a receiver roughly represents an S9 signal. A 'scotch' S-meter will indicate S9 at around 150 uV. Now, 50 uV in 50 ohms is a signal level of -73 dBm.

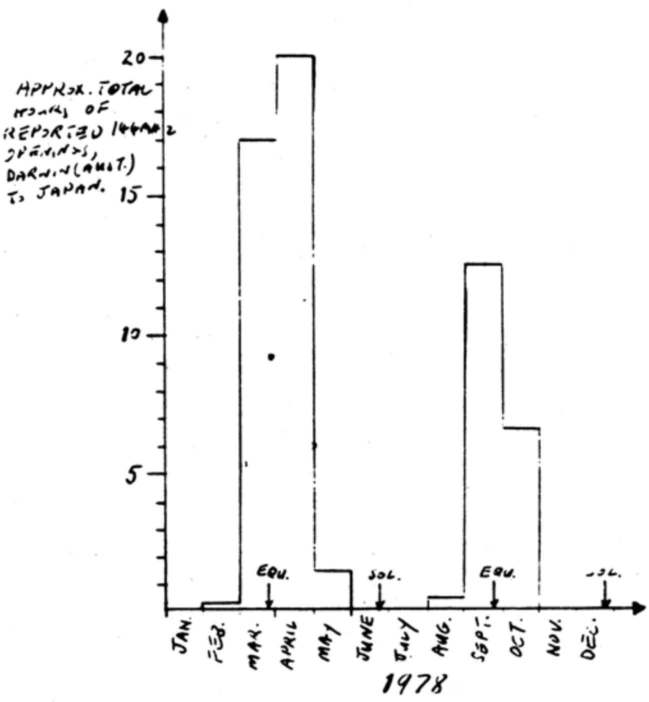


Figure 6. **Seasonal occurrence rate of 144 MHz propagation between Darwin and Japan, derived from the reports of VK8GB, during 1978 expressed as total hours during each month that openings were observed. Again, there is a strong equinoctial dependence evident.**

Month	Day	Times (UT)	Areas	R.S. @ Vanimo
Oct. 77	27	1230-1255	JE2	1
Feb. 78	21	1237		1
	23	1200		0
	24	1200	6	0
	25	1145-1150	4,6	1
Mar. 78	4	1228	6	1
	6	1045-1145	4,6	1
	7	1142-1159	6	1
	8	. . .	4,6	1
	9	1218-1225	6	0
	10	1148-1220	6	0
	11	1100-1216	4,6	1
	12	1100-1208	4,5,6	1
	18	1125-1137	4,6	1
	19	1206-1232	4,6	1
	20	1152-1259	4,6	1
	23	1149-1321	4,6	1
	24	1037-1224	4,6	1
	25	1110-1224	4,6	1
	29	1130-1241	6	1
April 78	2	1146-1155	6	1
	6	1122-1223	4,6	1
	7	1116-1304	4,6	1
	8	1120-1230	6	1
	9	1117-1220	6	1
	10	1107-1250	4,6	1
	12	. . .		1
	13	1135-1155	4,6	C
	14	1058-1205	3,4,6	1
	16	1117-1213	5,6	1
	17	1105-1157	4,6	1
	21	1112-1139	4,5,6	1
	23	1103-1218	4,6	1
	26	. . .		0
	27	1255	6	1
	29	1238	6	C
	30	1120	5	C
May 78	4	. . .		0
	5	1225	4,6	1
	8	1155-1200	6	1
	10	1210	4	1
August 78	11	1232	6	1
Sept. 78	7	1144	6	1
	11	1118-1135	4,6	1
	12	1140	4,6	C
	13	. . .		1
	14	1118-1123	4,6	1
	15	1102-1119	6	1
	16	1105-1138	4,6	1
	17	1202		S
	18	1050-1217	4,6	1
	21	1143-1223		1
	22	1158-1259		1
	23	1137-1202		1
	24	1057-1144		1
	25	1052-1158		1
Oct. 78	5	1202-1213		S
	7	1153-1157		1
	8	1142	6	1
	12	1140-1241	6	1
	13	1144-1157	6	1
	14	1150-1203		1
	15	1110-1241		1

144 MHz contact between Darwin and Japan as reported by VK8GB, between October 1977 and October 1978. In the far right column a '1' indicates range-spreading (R.S.) observed at Vanimo after 1000 Z, a '0' indicates R.S. not observed, 'C' indicates equipment failure and 'S' indicates interference obscuring observation.

The existence of range-spreading on ionograms taken at Vanimo (PNG) is a necessary, but not sufficient, condition for Class II (nighttime) TEP between Japan and Australia (MacNamara).

Consider the free space path loss at 144 MHz over a distance of 6400 km. (LU5DJZ to KP4EOR). Using the good books, a figure of 152 dB is obtained. Knowing the powers used by these two stations, their antenna systems etc, I estimated the signal, over a free space path, from LU5DJZ, received by KP4EOR would be at -66 dBm.

This exceeds the 'guesstimate' S9 by 7dB, i.e.: the S9 + report accords fairly well with a loss over the transequatorial path *equal to, or better than free-space path loss figures!* This is consistent with Class II TEP observations carried out by researchers over many years.

A similar analysis for more modest stations, such as used by Australian and Japanese amateurs on 144MHz gives received signals strengths, for a free-space path of the same length as the JA-VK TE path (5000 km), of around -85 dBm. This represents strength seven on the guesstimate signal strength scale (based on 6 dB per S-point). Reported signal strengths for many Australasian TEP contacts on 144 MHz are in this region.

I hardly think a *scatter mode* is responsible for the contacts.

When the areas of frequent contact are examined, further evidence of consistency with criteria for Class II TEP is found.

An examination of the areas worked from Darwin shows a very narrow strip covering the island of Shikoku and the southern half of Honshu — between geomagnetic latitudes 21-22° North. Darwin is at a geomagnetic latitude of 22° South making the path terminals very nearly conjugates.

Unmistakenly, these results are consistent with the major characteristics of evening-type or Class II TEP.

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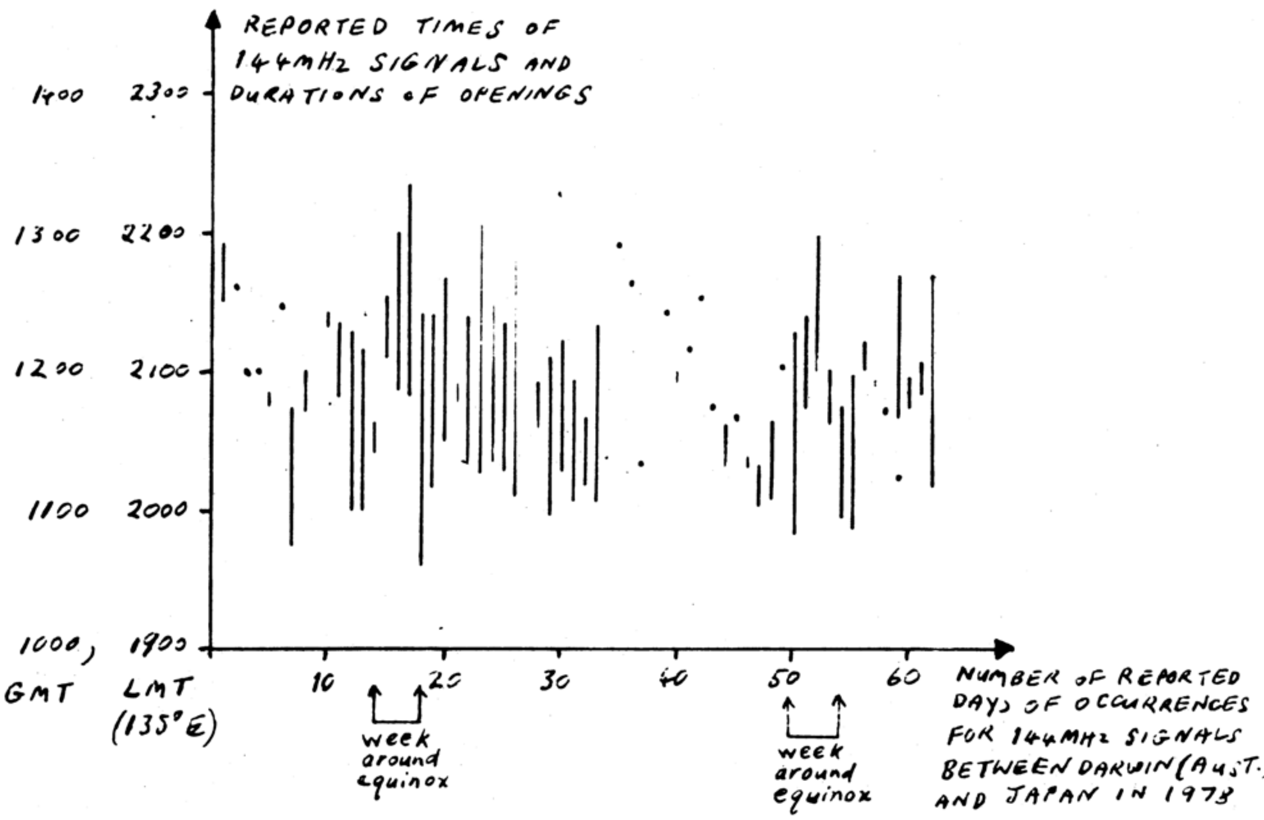

Figure 7. **Diurnal occurrence pattern of 144 MHz propagation between Darwin and Japan, derived from the reports of VK8GB, during 1978. Few openings commence before 2000 hours local mean time (LMT) and few last beyond 2200.**