SPACED DIRECTION FINDING MEASUREMENTS OF VERY LOW LATITUDE WHISTLERS AND THEIR PROPAGATION MECHANISM

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1. Introduction

Whistlers are the VLF electromagnetic waves which propagate through the magnetosphere after originating in the lightning discharges in the opposite hemisphere, and so they have been utilized as a useful tool of studying the dynamics and structure of the magnetosphere (Helliwell,1965).

Hayakawa and Tanaka(1978) have comprehensively reviewed the observations and theories of whistler propagation at lower latitudes, and suggested the importance of very low latitude (geomag.lat. less than 20°) whistlers in the general whistler studies. The propagation characteristics of whistlers at very low- and equatorial-latitude whistlers are poorly understood and the extensive study of them leads us to solving the fundamental problems in the whistler propagation including the duct trapping, duct leakage, transmission down to the ground,etc. which are not so well understood even at higher latitudes.

Hence, we have carried out the spaced direction finding measurements of low- and equatorial-latitude whistlers in South China, and this paper presents the observing system, analysis system(direction finding), observational facts and discussion on the propagation mechanism.

2. Observational system and direction finding measurements

The three stations are adopted in our VLF campaign;(1) Zhanjiang(ZJ) (geomag.lat. 10.0°), (2) Guilin(GL) (14.1°) and (3) Wuchang(WC) (19.4°) as given in Fig.1, which form a network aligned nearly in the same meridian plane. At the two stations of ZJ and WC we have observed simultaneously three field components (two horizontal magnetic field components and one vertical electric field component) over a wide frequency band (0-10 kHz) by means of the digital recorders. While,

Fig.1 The location of three whistler stations in South China

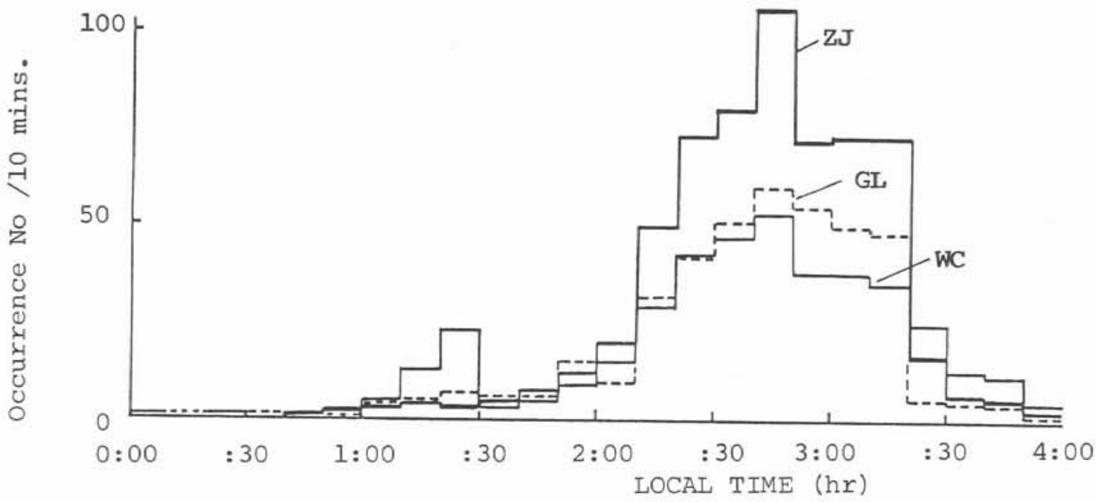

Fig.2. The temporal evolution of whistler occurrence rates at the three stations on 5 January,1988.

the same recording by means of an analogue recorder has been made at GL.

The observation has been carried out during the period of 5th to 11th January,1988, and the L.T. interval from 0h oom to 04h 00m was continuously covered in order to accumulate more data because whistlers at very low latitudes are found to be received only in the night (Liang et al.,1985).

The simultaneous measurement of three field components makes it possible to perform any kinds of direction findings (field-analysis method (Okada et al.,1977,1981; Ohta et al.,1984,1987; Ohta,1986), goniometric triangulation (Hayakawa et al.,1981) and wave distribution method (Shimakura and Hayakawa, 1987)).

3. Observational results of very low latitude whistlers

The results on a particular day of 5th January were presented in this paper because a lot of whistlers were observed at the three stations on this day. Fig. 2 illustrates the temporal evolution of the occurrence numbers of whistlers at the three stations. We notice an enhanced maximum at L.T. = 2:00-3:00 and a secondary peak just before L.T. ~ 1:30. We first discuss the characteristics of the main peak. Fig.3 illustrates an example of a whistler (dispersion=10.5 $sec^{1/2}$) simultaneous to all stations, and,as seen from Fig.2, the occurrence rate at

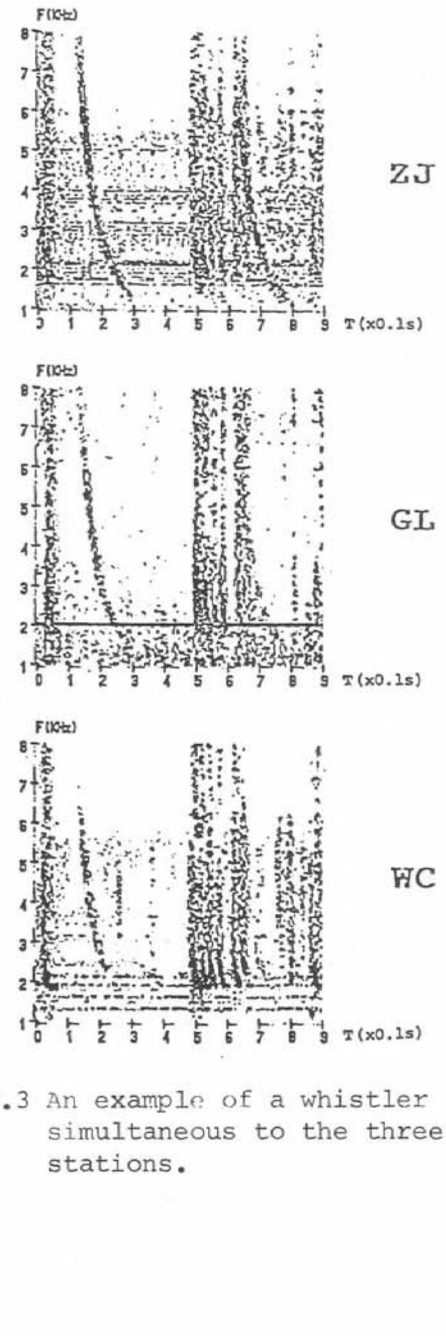

Fig.3 An example of a whistler simultaneous to the three stations.

ZJ is much more enhanced than that at GL and WC. The arrival direction and wave polarization of whistlers observed at ZJ (L.T. ~2:00-3:00) as determined by the field-analysis method are plotted in Figs.4 and 5. The ionospheric exit points are concentrated in a small area with diameter being about 50km in the zenith of the station of ZJ and Fig.5 indicates that the average polarization is distributed just around the right-handed circular(u=o,v=1). A combined consideration of Figs.4 and 5 suggests that the whistlers have penetrated through the ionosphere near ZJ at a geomagnetic latitude of ~10°.

The wave polarization of the simulataneous whistlers has been measured at GL and WC, and it is found(although not shown) that it is generally elliptical at GL and nearly linear at WC. Hence,the goniometric direction finding measurements have been made at GL and WC,which enables us to locate the ionospheric exit region by triangulation in Fig.6. It is found that the goniometric triangulation result in Fig.6 is consistent with the previous field-analysis direction finding result in Fig.4. So,the whistlers simultaneously observed at GL and WC are the consequence of the Earth-ionosphere waveguide mode propagation after emergence near ZJ.

We next discuss the secondary occurrence peak at L.T. 1:20. The dispersion is slightly enhanced,13.0 $sec^{1/2}$ as compared with that of the main peak just before L.T. 3:00. This enhanced dispersion indicates that the path latitude is higher than that for the main peak(~10°). Being consistent with this expectation,the occurrence rate is greatly enhanced only at WC,and a very

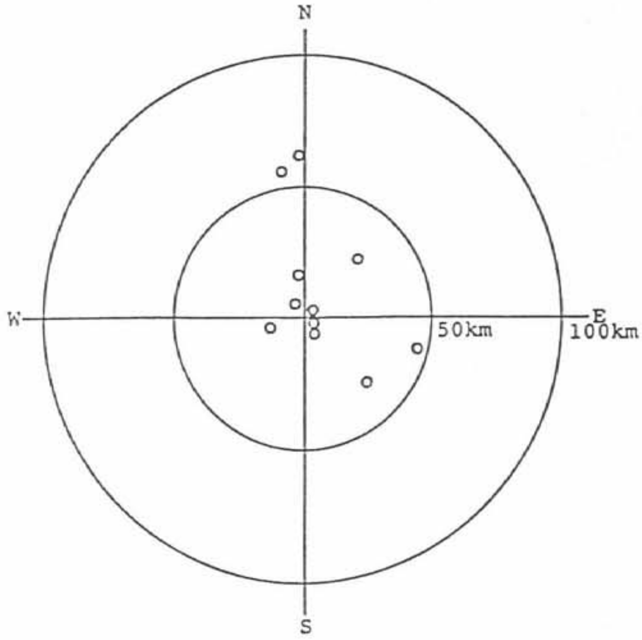

Fig.4 The distribution of the ionospheric exit points of whistlers as determined by field-analysis method.

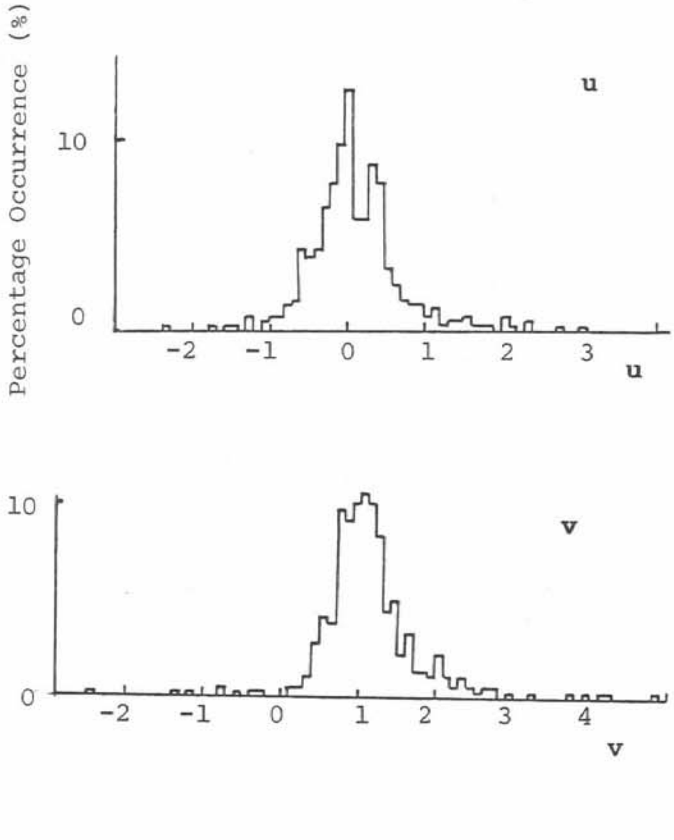

Fig.5 The occurrence histogram of the measured wave polarization(u and v). u=0,v=1 corresponds to a right-handed circular polarization.

small peak is found at GL and WC. This kind of characteristics is in good agreement with our previous tendency for low latitude (20-30°) whistlers that they tend to propagate towards higher latitudes after the ionospheric transmission (Hayakawa and Tanaka,1978).

4. Propagation mechanism of very low latitude whistlers

It is found as based on our first direction finding measurements that there is present a preferred path of propagation channel at the geomagnetic latitude range from 10° to 13°. Andrews(1978) and Thomson (1987) have suggested from their ray-tracing study of non-ducted mode propagation that there is a preferred non-ducted prolongitudinal channel at geomagnetic latitude around 10°. However,their possible ionospheric exit region is estimated to be about 1° in latitude (~100 km),which is in sharp contrast with our direction finding result indicating a much smaller exit region. Furthermore,the tendency of poleward propagation after the ionospheric transmission,which is exactly the same as found at low latitudes (20°-30°)(Hayakawa and Tanaka,1978). These results are again satisfactorily interpreted in terms of ducted propagation of whistlers even at very low latitudes. The duct diameter is less than 50km and the duct life-time is slightly smaller than the value at low latitudes.

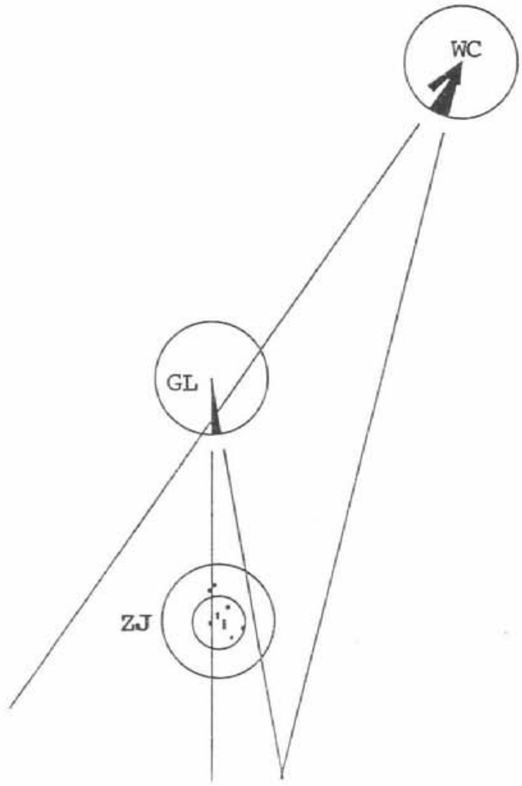

Fig.6 Localization of the ionospheric exit region of whistlers as determined by the goniometric triangulation from GL and WC.

References

Andrews, M.K.; J. Atmos. Terr. Phys., 40, 429-436, 1978.
Hayakawa, M., and Y. Tanaka; Rev. Geophys. Space Phys., 16, 111-123, 1978.
Hayakawa, M., Y. Tanaka, T. Okada, and A. Iwai ; J. Geophys. Res., 86, 6781-6793, 1981.
Helliwell, R.A.; Whistlers and Related Ionospheric Phenomena, Stanford Univ. Press, 1965.
Liang, B.X., Z.T. Bao, and J.S. Xu; J. Atmos. Terr. Phys., 47, 999-1007, 1985.
Ohta, K., M. Hayakawa, and Y. Tanaka; J. Geophys. Res., 89, 7557-7564, 1984.
Ohta, K.; Doctoral Thesis, Nagoya Univ., Nagoya, 1986.
Ohta, K., M. Tian, C.C. Tang, K. Baba, and H. Eguchi; Mem. Faculty of Eng., Chubu Univ., 23, 45-51, 1987.
Okada, T., A. Iwai, and M. Hayakawa; Planet.Space Sci., 25, 233-241, 1977.
Okada, T., A. Iwai, and M. Hayakawa; J. Atmos. Terr. Phys., 43, 679-691, 1981.
Shimakura, S., and M. Hayakawa: Proc. Chapman Conf.on Plasma Waves and Instabilities in Magnetospheres and at Comets, 180-183, 1987.
Thomson, N.R.; J. Atmos. Terr. Phys., 49, 321-338, 1987.