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EXPERIMENT OF SHORT WAVE COMMUNICATION AND THE INVESTIGATION OF THE PROPAGATION BEARINGS BETWEEN THE GREAT WALL STATION AND XINXIANG

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Abstract The distance from the Great Wall Station (62.2° S, 58.9° W) to Xinxiang (35.3° N, 113.8° E) is 16981 km. The path passes through the polar cap absorption region and the auroral absorption zone, and it is across the equator.

In this paper firstly the effects of short wave communication and usable time blocks and frequency ranges between the Antarctic Great Wall Station and Xinxiang from December 1985 to March 1986 are introduced. The comparison between the usable frequency ranges with the estimated MUF is made. The upper limit of frequency ranges of communication along the short great circle path basically agrees with the MUF but there is difference between them along the long great circle path.

Secondly, the result of the propagation bearings experiment in January to February 1986 is introduced in more detail, The propagation along the great circle path from the Great Wall Station to Xinxiang is the main propagation mode. But the propagation along non great circle paths occurs at times between Great Wall Station and Xinxiang. The non great circle path propagation varies with time because the ionospheric absorption and other conditions which support the non great circle path propagation are the function of the time. So the courses of the non great circle path propagation may be different in the different time. The mechanism of the constructing non great circle path propagation has been analysed. We preliminarily think the main cause of propagation along non great circle path is the ground scatter. The stronger radialization of the side lobes of the antenna and the less absorption of the ionosphere contribute to forming non great circle path propagation.
Key words Communication experiment, Great Wall Station, Xinxiang Station, Propagation bearings.

1. Introduction

The distance of the short wave communication path from the Great Wall Station (GWS) to Xinxiang is 16981 km. The path passes through the cap absorption region and the auroral absorption zone and it is across the equator.

When the GWS was being built at Jan. 1985, for first communication between the GWS and Beijing the antenna used was the dipole antenna of which the deviation from the bearings of great circle path is 85 degrees. When the cases of the communication between Beijing and the salvage ship were introduced by Yuan Yi, he said that when the GWS was being built, the liaison could not be made along the great circle path but the communication evidently took a turn for the better during the bearings of antenna deviated from the great circle path. The phenomenon existed throughout in the Antarctic sea area communication for two months. Consequently we made the experiment of time blocks and frequency ranges of the short wave communication and the propagation bearings between Jan. and Feb. 1986.

According to the experiment, we not only can determine the usable time blocks and frequency ranges of this path but also prove that the propagation along the great circle path is the main propagation mode in the communication system and there exists simultaneously the non great circle path propagation. As it was thought by Miya (Miya, 1955) and Hagg (Hagg, 1963) that the mechanism of the constructing non great circle propagation is the ground scatter. According to the propagation mechanism inference, the sloping antenna in the direction of 286 degrees and the dipole antenna in the direction of 282 degrees were built at GWS in Jan. 1986. It is proved that the communication can be made with the two antennas indeed.

Besides we have discovered that the signal can be received when the bearings of the receiving antenna and transmiting antenna are in the same direction. This phenomenon is accounted for that the radialization of the side lobes of the antenna is scattered by the ground.

2. The Communication Time Blocks and Frequency Ranges of the Measurement

The measured results of communication time block and frequency ranges with the system of the short wave communication in Jan. 1986 are given in Fig. 1 and Fig. 2. The points in the figures show the measurement of each time when the signal strength is greater than the first grade (the communication can be made at that time). The curves plotted in Fig. 1 and Fig. 2 show the predicted basic maximum usable frequencis. South path or north path in the figures means that the path from Xinxiang passes by south polar (short great circle path) or north polar (long great circle path) to GWS. Fig. 1 and Fig. 2 show the results received at Xinxiang and at GWS respectively. It can be seen from the figures that the better time blocks of communications are from 6 o'clock to 10'o'clock and from 18 o'clock to 23 o'clock. The usable frequency ranges for above-mentioned two time blocks are about from 8 MHz to 14MHz and from 9 MHz to 17 MHz respectively. The upper limit of frequency ranges of communication during 18 o'clock to 23 o'clock along the short great circle path basically agrees with the predicted basic MUF. During 6 o'clock to 10 o'clock, the upper limit of frequency ranges lower than the predicted basic MUF. During 10 o'clock to 18 o'clock and 23 o'clock to 6 o'clock, even if the transmiting signal can be received, the signal quality is very poor and it is usually lower than the second grade.

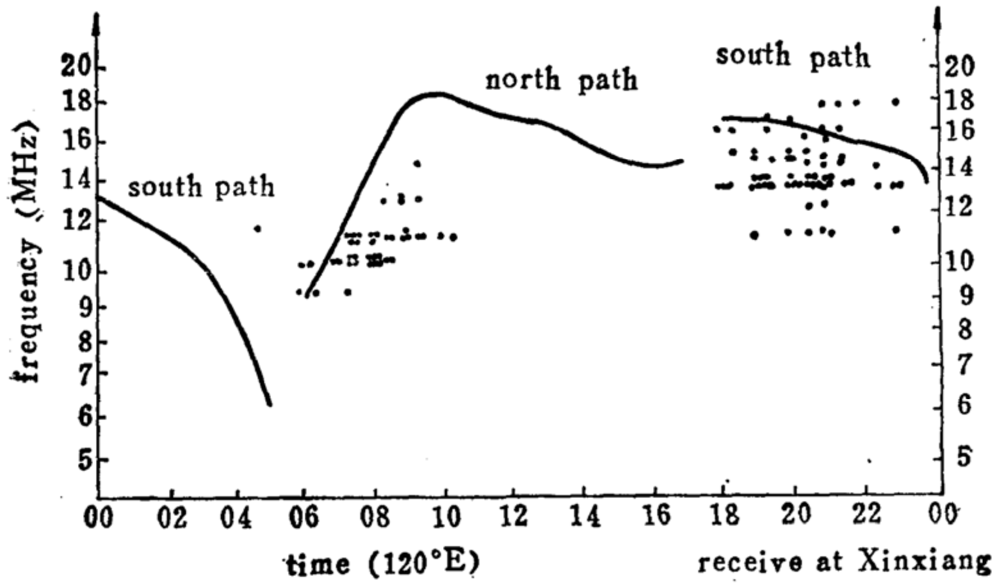

Fig. 1 The usable frequency bands and time blocks received at Xinxiang,

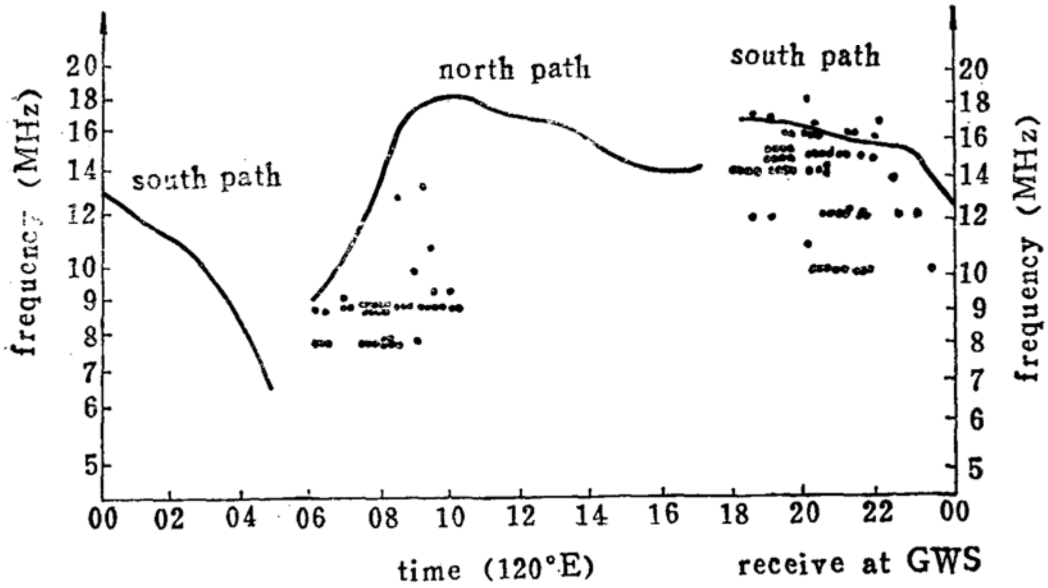

Fig. 2 The usable frequency bands and time blocks received at GWS.

3. The Results of Propagation Bearings Experiment

In order to investigate the better bearings of communication, the quantitative measurements for the signal strength was made. The results of bearings experiment show that for the long distant communication path from GWS to Xinxiang not only radio wave can propagate along the two great circle paths but also there are non great circle path propagations (NGCP). The results of the propagation bearings experiment are given as follows.

1. The Propagation along the Great Circle Paths (GCP)

The bearings of the rhombic antenna at the GWS is directed to Beijing. The two bearings are 170.5 degrees. and 350.5 degrees. The bearings from the GWS to Xinxiang by the north polar is 347 degrees and the other by south polar is 167 degrees. Therefore, Xinxiang is in the beams of the rhombic antenna. When the signal is received with the rotating log-periodic antenna at Xinxiang the signal strength is recorded once every rotating 30 degrees. An example of the normalized strength of the signal transmitted with the frequency of 14.777 MHz to south by the rhombic antenna at the GWS and received to south by rotating log-periodic antenna at Xinxiang at 21:05 on Jan. 15, 1986 is given in Fig. 3. We can see from Fig. 3 that the signal strength has a maximum at the 180 degrees i.e. the bearings of the southern path. The circumstance always occures in a very wide frequency ranges at 18:00 to 23:00 (120° E). Similarly the strength of the signal transmitted with the frequency of 12.825 MHz to north by the rhombic antenna at 09:00, 10:00, 13:00 (120°E) on the Jan. 29, 1986 is shown in Fig. 4. We can see from Fig. 4 that the peak of signal strength is not only at the northern path bearings (7.4 deg.), but also is distributed over a wide range around the 360 degrees. The propagation circumstance along the northern path is usually the case at A.M.. The circumstance received by rotating log-periodic antenna at Beijing is basically as above.

2. The Propagation along Non Great Circle Path (NGCP)

It merits attention that when the conditions of time and bearings are suited to propagation

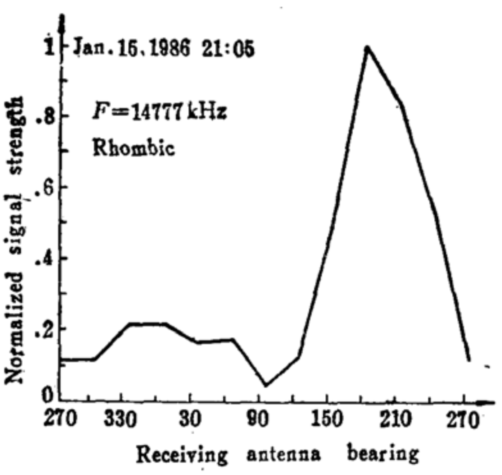

Fig. 3 The strength of signal received at Xinxiang.

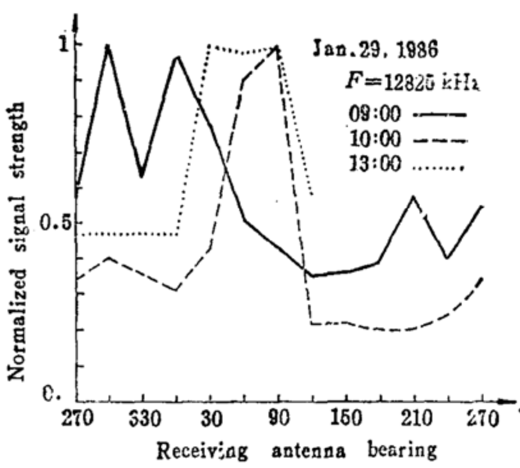

Fig. 4 The strength of signal received at GWS.

there are some NGCP besides the propagation along the GCP.

Between the shore station (Beijing) and salvage life saving ship J121, the bearings from Beijing to ship is 190 degrees. From Dec. 1984 ot Feb. 1985, the liaison between Beijing and the ship could not carry out at about 190 degrees bearings, but the communication was better at the 111 degrees. We preliminarily made an approach to the propagation mechanism for the NGCP in 1985. According to the inference there should be a NGCP the bearings of which would be in the direction of about 121 degrees for Xinxiang and in the direction of about 286 degress for GWS at about 17:00. Thereupon we erected the sloping V antenna in the direction of 286 degrees and the dipole antenna in the direction of 282 degrees at GWS. The results of experiment show that the communication with the sloping V antenna or dipole antenna for receiving not only can be carried out (see Fig. 5 and Fig. 6) but also the signal received with the sloping V antenna is sometimes stronger than that with the rhombic antenna. In addition we discovered that whether transmitting or receiving was carried out at Xinxiang, the stronger

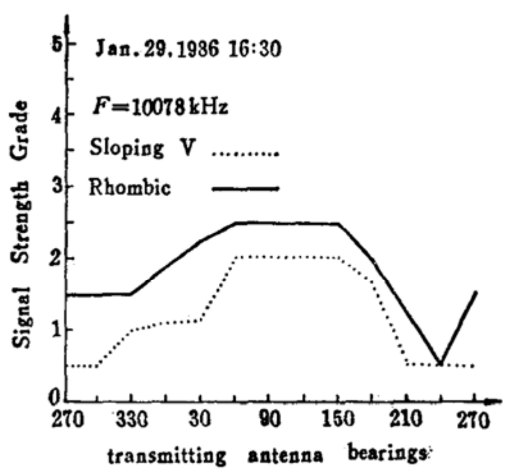

Fig. 5 The strength of signal received at GWS.

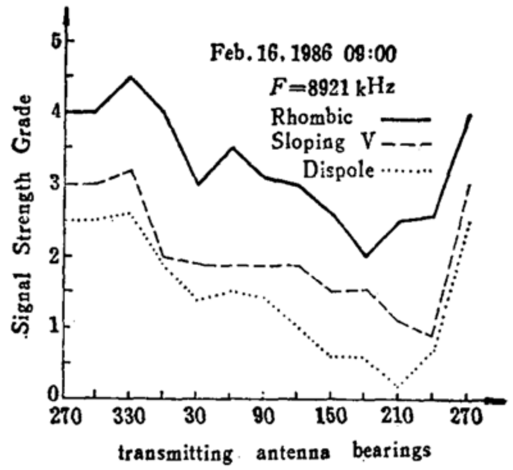

Fig. 6 The strength of signal received at GWS.

signal often appeared in the direction of about 330 degrees as shown in Fig. 6. Fig. 5 and Fig. 6 show the grade of the signal transmitted with the rotating log-periodic antenna at Xinxiang and received at GWS. Furthermore, the result measured by log-periodic antenna array in the direction 302 degrees at Xinxiang shows that the transmitting or receiving efficiency is better than by rhombic antenna at about 06:30. Before 06:00 and after 8:00, the strength of signal becomes weaker or even the signal can not be received.

It is more peculiar that the communication can be made with the transmitting antenna and receiving antenna all in the same direction.

4. The Analysis of the Propagation Mechanism for the NGCP and the Discussion of the Optimal Transmission Direction

1. *The Analysis of the Propagation Mechanism*

Some propagation phenomena of NGCP are introduced in above. Now we analyse and discuss the propagation mechanism of them.

After the radio wave is transmitted, it propagates in the medium along all the paths sufficing the propagation conditions until the energy of the wave exhausts. Generally, the radio wave propagates along the less loss GCP. but sometimes the loss of energy is less along the NGCP or even the loss of energy is less than along the GCP, naturally the radio wave propagates along NGCP to the receiver.

The causes of constructing the NGCP propagation are nothing but that the tilt of the ionosphere, the ground and ionosphere scatter (Davies, 1965). Of course, the radio waves must have enough energy to support the propagation along the path, such as the radiations of the antenna are powerful along the NGCP. The rhombic antenna has more lobes. It can be seen from the antenna diagrams (CCIR, 1984) that the rhombic antenna at GWS and Xinxiang all have same lobes in the direction of 40°, 60°, 80°.

Except that the large ionosphere tilt appears by two sides of the equator and during the sunrise or sunset, generally it is not often occurs. The direction of ionosphere tilt around the equator mainly is in north and south. In our case, the propagation direction of GCP is also in north and south. Therefore this tilt aroud the equator can only lead to the variation of the angle of incidence of wave in the vertical plane of GCP as the "TEP" propagation mode (山冈诚, 1972). So the probability of large deviation of wave propagation path from GCP in east or west direction can hardly exist. During the sun rise or set, the ionosphere is not tilted s uch as to make the propagation paths have a large deviations of 60 deg. from GCP (Zhao, 1986).

The occurrence of NGCP propagation varies with diurnal time because the ionospheric absorption and other conditions which support the NGCP propagation are the function of diurnal time. So in different time the course of the NGCP propagation can be different. During 16:00 to 23:00, the wave is radiated to region P1 (46° S, 103° W) (see Fig. 7) with the rotating log-periodic antenna in the direction of 120 deg. or with the southern rhombic antenna which has a side lobe in the direction of 122 degrees at Xinxiang. Then the waves are scattered by region P1 and propagated by the ionosphere reflection to the GWS. The bearings from the GWS to P1 region is 282.3 degrees. The wave propagated along this NGCP suffers less absorption in the time block and the NGCP is not through aurora absorption zone. Therefore the signal received is stronger. In addition, owing to the rhombic antennas with side lobes the comm-

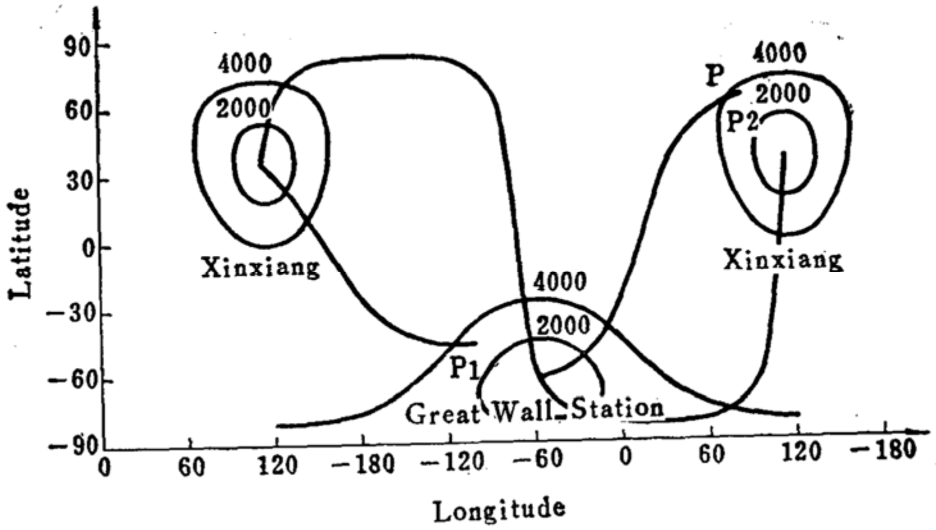

Fig. 7 The GCP and NGCP between GWS and Xinxiang

unication can be made with the northern rhombic antenna at GWS and with the southern rhombic antenna at Xinxiang.

A stronger signal strength always appears around the bearings of 330 degrees for Xinxiang during 06:00—10:00 (120° E) whether transmitting or receiving. The reason may be that when radio wave is transmitted northward with the rhombic antenna at the GWS, some is radiated to region P (62.5° N, 81° E) (see Fig. 7) through a side lobe of the bearings of 80 deg., then scattered by ground and propagated by the ionospheric reflection to the rhombic antenna with a side lobe of the bearings of 320° at Xinxiang. Although this propagation path is longer than GCP, the ionospheric absorption is small in the above time and no auroral absorption exists. So, stronger field strength will appear around the bearings of 330°. The bearings of the GWS and of Xinxiang to the region P are 77° and 333° respectively.

The communication between Xinxiang and GWS passes through day and night and the four season. Therefore some ionospheric inhomogeneous structures, such as spread F, which varies with day and night and seasons, usually appear on some NGCP. These inhomogeneous structures can cause the scatter of radio wave. For example, the waves received at Xinxiang may be caused by the scatter of spread F often appearing in latitude 80° N at night of winter.

It can be known that the propagation along the NGCP between GWS and Xinxiang is reversible.

2. *The Discussion of Optimum Transmission Bearings*

As mentioned above, the SW communication along the GCP between GWS and Xinxiang is main propagation mode. But it can not be simply thought that the optimum transmission bearings are the bearings of southern short GCP, because the optimum transmission bearings vary with the diurnal time. Secondly, it relates also to the frequency. Such as during the 8:00 to 10:00, the optimum transmission bearings are the bearings of northern path and during the 18:00 to 20:00, the optimum transmission bearings are the bearings of southern path. We have calculated with 11 MHz the field strength of the GCP and of the NGCP through P region and P2 region between GWS and Xinxiang respectively. In calculation of the field strength we

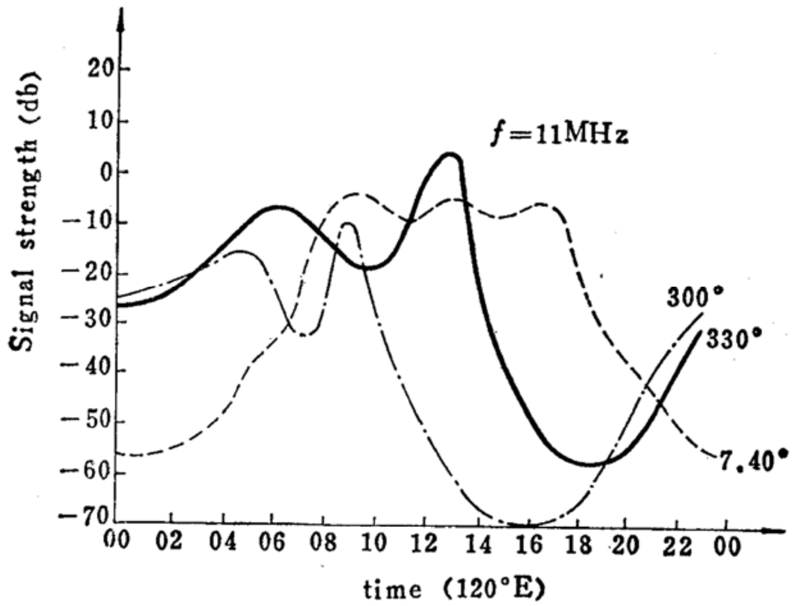

Fig. 8 The optimal transmission bearings variation with time.

take account of the scatter loss. The results of the calculation are plotted in Fig. 8. The solid line and dashdotted line show the field strength values of wave propagating along the paths through P region and P2 region respectively and the dash line shows the field strength values of the wave propagating along the northern GCP. The bearings from Xinxiang to P and P2 are 333 deg. and 300 deg. respectively. It can be seen from Fig. 8 that the maximum of the field strength along these paths, i.e. the optimum transmission bearings gradually transfer with time shifting from northwest to north. This is used in the communication between Xinxiang and GWS. At Xinxiang at 6:00 we begin to communicate with GWS by the log-period antenna array. At about 7:30 the signal gradually becomes weak. Then we change to use the northern rhombic antenna after 8:00 and the signal becomes strong again.

5. Conclusion

It is perfectly feasible that the current SW communication system between Xinxiang and GWS can be used in a difficult, remote area communication, Provided the latent power is fully excavated and the frequency and time block are scientifically utilized, the communication effect will be fine.

It is derived from the experiment that during the weather of the solar low active period the usable time blocks and frequency ranges of communication between GWS and home are 6:00 to 10:00, 8MHz to 14 MHz for the northern path and 18:00 to 23:00, 9MHz to 17MHz for the southern path. For the southern path the calculated MUF and usable time blocks conform to those of experiment. For the northern path the calculated MUF is higher than that of measurement and the calculated usable time block greater than that of fact. Especially, the estimated signal strength between 10 o'clock and 17 o'clock is very strong and the estimated frequency ranges in above time block are very wide but in the time block the communication is difficult.

The experiment shows that the NGCP is usually structured by the scatter effect. Therefore during the estimating communication path we not only take account of the possibility to utilize short and long GCP but also should estimate the possibility to utilize the NGCP according to the character of antenna and the different time to excavate the latent power of communication paths.

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