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The strategies for coast radio stations in China under the opening of Arctic Northeast Route

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THE STRATEGIES FOR COAST RADIO STATIONS IN CHINA UNDER THE OPENING OF ARCTIC NORTHEAST ROUTE

By

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DECLARATION

I certify that all the material in this research paper that is not my own work has been identified, and that no material is included for which a degree has previously been conferred on me.

The contents of this research paper reflect my own personal views, and are not necessarily endorsed by the University.

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Date: 1 July, 2017

Supervised by Professor Yang Tingting

Dalian Maritime University

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ABSTRACT

Title of Research paper: **The Strategies for Coast Radio Stations in China under the Opening of Arctic Northeast Route**

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The Arctic route has been called the "Golden route" by the maritime industry, and it is the nearest water route connecting China with Europe and America. Marine energy transportation is one of the China irreplaceable forms of transportation. Nowadays, China is under the tensions in the South China Sea. The opening of the Arctic route provided China with another marine energy transportation alternative, and thus has important strategic significance. The Arctic route reduces 12-15 days(Wang,2011) compared with the traditional route, greatly reducing the ship fuel consumption and carbon dioxide emissions, as a result, the energy and business efficiency are improved, and new opportunities are created for the development of the international shipping market. From the perspective of maritime transport efficiency, along with the opening of Arctic route, world maritime transport pattern will be greatly changed. The distance between China and the European market will be greatly shortened, which will lead to changes in the international division of labor and industrial layout, thereby affecting the Chinese coastal industrial division of labor and economic development. Judging from the overall commercial operation of the Arctic route, experts believe that the development trend of the Arctic route is irreversible. Russia predicts that the navigable time of the Arctic route will reach five months available for navigation by 2020(Shi, 2010), which will bring great economic value.

Shipping safety is an important concern for the international maritime industry. Search and rescue cannot work without the support of communication; the impact of inclement weather on the ship is also an important factor to the safety of navigation. Releasing navigation warning to prevent the maritime distress and accident has been one of the focuses of the international maritime organization. At present, the coverage of satellite in Arctic area is limited, the coasts are lack of relative infrastructure, coastal pier, lighthouse instructions, CRS (coast radio station), and mobile phone base station. Providing shortwave communication service for the Arctic route will be one of the important means to ensure the safe navigation of the Chinese fleet in the Arctic route. This paper is aimed at studying the choosing of shortwave frequencies between CRS in China and Northeast Arctic Route, to find the best solution, concerning the characteristics of shortwave communication and combined with the Arctic polar ionosphere electromagnetic environment characteristics. Given that special communication environment puts forward higher requirements on the CRS construction, this paper focuses on the communication between four coastal radio stations and Arctic route: Harbin, Tianjin, Shanghai, Guangzhou, through studying on electromagnetic environment of them. Give suggestions about choosing of communication frequency for different CRS in different time. And give recommendations of CRS infrastructure development, including antenna gain and antenna elevation pattern. Giving specific solutions that can be implemented in the future in the construction of application with a high reference value.

This paper puts forward a specific scheme for SHORTWAVE communication between China and Arctic route, which can be used as a guide for SHORTWAVE communication of Chinese Arctic sailing ships. It provides a more authoritative theoretical basis for the better service for the ships in Arctic route by CRSs in China, and also provides guidance programs and technical support for the construction of communication support facilities for China.

KEYWORDS: Northeast Arctic route, short-wave Communication, Coastal radio station

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LIST OF ABBREVIATIONS

MSA	Maritime Safety Administration
MUF	Maximum Usable Frequency
LUF	Lowest Usable Frequency
SNR	Signal Noise Ratio
SF	Spreading F layer
CRS	Coast Radio Station
ITU	International Telecommunication Union

Chapter 1

Introduction

1.1 The background and significance of this research

The Arctic region refers to the area within 66°34′N of the Arctic Circle. The Arctic region includes the entire Arctic Ocean, as well as parts of these 8 countries, Greenland, Canada, the United States, Alaska, California, Russia, Norway, Sweden, Finland and Iceland.

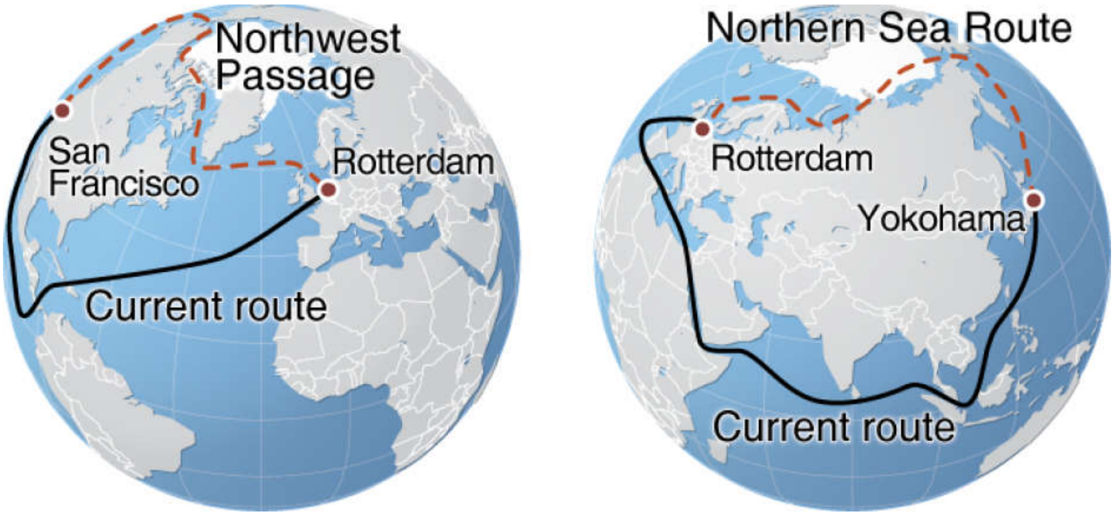

Figure1.1 Sketch map of Arctic route
Source: The Arctic Journal, (2017). *Container ship's journey highlights prospect, challenges of Arctic routes*

The Arctic route (shown in Figureure 1) has been called the "Golden route" by the maritime industry, which includes the northeast route and the northwest route. The entire voyage of Arctic northeast route is about 2936 nm from east to west, sailing through the Bering Strait, the Chukotka sea, the Delang Strait, the East Siberia sea, the North Sea, the Novosibirsk islands, the Rapp Jeff Vilkitsky, the Kara Sea and the Barents Sea, the northern New Island, arrived in Norway near North Point, eventually to European ports. It is the nearest route linking China and Europe on the water route. From the point of view of maritime transport efficiency, the route will save 12-15 days (Wang,2011) by Arctic than traditional routes. The "Golden route" once opened, the world maritime transport pattern will be greatly changed, will greatly shorten the distance between China and Europe, North America and other markets, led to the international division of labor and industrial layout changes, thereby affecting the Chinese coastal industrial division of labor and economic development. Judging from the overall commercial operation of the Arctic route, experts believe that the development trend of the Arctic route is irreversible.

At present, the situation in the South China Sea is tense, and maritime energy transportation is one of China's irreplaceable forms of transportation. The opening of the Arctic route also opens up another maritime energy transportation route for China. The strategic significance of the Arctic route is much greater than the commercial significance.

However, at present, there are fewer facilities of communication base station, no mobile phone signal, no navigation and beacon instructions, no radio facilities along the Arctic route. There is no satellite signal beyond the above 75°north latitude. Ship distress alarm and effective communication between ships and shore is difficult to guarantee. In fact, in addition to the iridium satellite, there are no other effective means of communication. So the research of shortwave communication is very necessary, and how to serve the communication for ships in Arctic route supported by CRS (Coast radio station) in China is an important issue to be studied.

1.2 Literature Review

The navigation safety and natural environment protection of ships in polar waters have always been an important topic of concern in the international maritime industry. The 94th meeting of Maritime Safety Committee (MSC) in November 2014 and 68th meeting of Marine Environment Protection Committee (MEPC) in May 2015 respectively adopted the International Code for Ships Operating in Polar Waters ship (Polar Code) and the related international convention amendment as mandatory, which have entered into force in January 1, 2017. Chapter 10 contains the functional requirements of communication (functional requirements), regulations and guidance (additional).

Maritime Safety Administration of China took the lead in 2014 and 2015 to publish the Guidance on Arctic Navigation in the Northeast Route and the Guidance on Arctic Navigation in the Northwest Route. The requirements of ship communication equipment are summarized among them.

Through the above international and domestic rules, it can be seen that the ship polar waters navigation safety and protection of the natural environment has been an important concern of the international maritime industry, especially in recent years, and been greatly concerned to the government and experts. Current research mainly focuses on navigation and security for communications at general rule level, and there is no specific operational guidance, let alone for shortwave communication, which is an important method of communication, and there is no special research and scheme applicable for the CRS. This paper will study this blank field.

1.3 The main contents and methods of this study

Shortwave communication mainly relies on the wave on the frequency range of 2-30MHz, remote communication through the ionosphere reflection, thus restricting the shortwave communication by the ionospheric conditions. Signal strength will be reduced in the communication process due to the diffusion and absorption. In order to make sure the receiver has enough signal strength, we must study the influence factors, propagation characteristics and transmit rules, according to the mechanism of short wave propagation to find the best working frequency, design of communication link, to enable the communication to achieve the best results.

Frequency of shortwave goes hand in hand with the regional ionospheric state.The Arctic route goes the communication link region, and communication quality is influenced by the ionospheric characteristics, therefore it is necessary to study, collecting data, analysis and research the polar ionosphere, includes the distribution effects of solar storms, solar activity in the Arctic polar ionosphere, the time delay and frequency shift characteristics of the communication link.

For shortwave communication restricted by the ionospheric conditions, communication frequency selection is very important, for it ensures that neither the high frequency waves penetrate the ionosphere and not return to the ground, nor the work frequency is too low, wave energy from ionospheric absorption is too large, so that the signal is too weak and cannot even reach the receiver. In our practice, we highly appreciate the importance of choosing the frequency of work. The correct selection of working frequency can ensure the quality and the rate of communication. It is an important part in the design process of short wave communication. In the third chapter, we study the usable frequency range of all stations to the Arctic communication links. Given that the ionosphere has obvious seasonal, weekly,daily change, it is not reliable of any randomly chosen frequency in the short wave frequency band (2-30MHz) for a certain communication, in the path of a given distance and direction. At a certain period of time, the shortwave communication can only be used within a limited frequency band, the basic maximum usable frequency and lowest usable frequency parameters is the main concern when it comes to choosing the frequency of short wave communication.

The basic maximum usable frequency (basic MUF) is the highest frequency of refraction and reflection between transmitter and receiver, at a certain time. When the working frequency exceeds this frequency, the emitted electromagnetic wave will pass through the ionosphere and cannot be reflected back to the ground. The highest usable frequency is the most important parameter to be determined in short wave communication system design, and is the basis for computing other parameters. Generally, MUF decreases when the distance decreases.

The lowest usable frequency (LUF) is the frequency, with its Signal Noise Ratio

(SNR) being equal to the minimum required SNR for the receiver after receiving by the receiver through transmitting the ionosphere at a given time and under specific operating conditions. LUF relies on transmitter power, as well as path loss (frequency, season and geographical location, etc.) and noise level (which depends on frequency and reception location) and so on. One of these major factors is the ionospheric absorption, which results in LUF peaking at midday before the ionospheric absorption varies with the zenith angle of the sun.

LUF is the lower frequency limit of communication link, the lower the working frequency of communication link, the greater the absorption, the weaker the signal strength to reach the receiving point. Therefore, frequency selection is usually carried out according to MUF in the frequency selection, and LUF is used as reference only.

Of course, we should consider some anomalies: sometimes MUF may drop to a particularly low value (as during a storm), or LUF will be increased by D layer absorption. In this case, maybe there is no suitable frequency.

The International Telecommunication Union (ITU) gives the basic MUF calculation methods in the Rec.ITU-R, P.533 (ITU,2015) and Rec.ITU-R P.1240 recommendations(ITU,2015), and these are also the most widely used frequency calculation methods.

SNR is a major factor affecting short wave communication, which determines whether the signal can be detected from noise. SNR is the ratio of signal energy to noise power.

The Rec.ITU-R P.372 recommendation(ITU,2016) provides the median power of atmospheric noise received over a good ground receiving by a short, vertical, lossless monopole antenna, and gives the corresponding human and cosmic noise intensities. The synthetic external noise factor at the specified frequency f (MHz) is Fa (dB (kTb)), K is the Boltzmann constant, and T is the reference temperature of 288 K. Usually, the resultant noise factor is different from the Fa value when different receiving antenna are used. However, because of the lack of complete noise measurement data for different antennas, as the first approximation, it is assumed that the Fa value obtained by the ITU-R P.372 recommendation is appropriate. Thus, the median signal-to-noise ratio (dB) for the bandwidth B (Hz) is S/N:

$$S/N = Pr - Fa - 10\log10b + 204 \quad (1.1)$$

Among them:

Pr: the median power of the available receiver.

Therefore, the following parameters can be introduced to evaluate the communication capability of ground stations:

(1) The amount of available links

The amount of available links that can meet the terminal service SNR required, i.e. in a given time, between the LUF and MUF, there is at least one frequency to meet the terminal service required SNR, the communication link can be used.

(2) Rate of communication

The communication capability of ground stations is characterized by Rate of communication.

$$\text{Rate of communication} = \frac{\text{The amount of available links}(m)}{\text{The amount of links}(n)} \times 100\%$$

The amount of links is the fine grid division of the Arctic communication area, latitude and longitude 1 degrees according to the step division, a total of 168 communication points, the month according to 6-11 months, in accordance with the time point 0-23, so the number of total communications link for 168*6*24, a total of 24192.

(3) The percentage of the total number of frequencies that can be passed

The number of frequencies that can be used as a percentage of the total frequency reflects the frequency range available for each station.

$$\text{The percentage of the total number of frequencies to pass} = \frac{\text{The amount of available frequencies}(m)}{\text{The amount of total frequencies}(n)} \times 100\%$$

In order to achieve the desired quality level, the received signal level must be higher than the noise level, which requires a minimum RF SNR. The International Radio Consultative Committee suggested that audio SNR reached 6dB is barely available to 15dB for the commercial use, 30dB commercial good. This paper only in accordance with the terminal service required SNR is 6dB and 15dB, can be calculated pass rate.

1.4 Basic information about CRS

The locations of domestic stations: Guangzhou, Shanghai, Tianjin and Harbin. The detailed information is shown in Table 1. The distance of ground stations from the Arctic region is shown in Table 2.

Table 1.1 Locations of CRS

Region	location	Geographical coordinates	
		latitude	longitude
South China Sea	Guangzhou CRS	23°22′	113°29′
East China Sea	Shanghai CRS	31°11′	121°38′
North China Sea	Tianjin CRS	39°00′	117°42′
	Harbin CRS	45°45′	126°40′

Source: Completed by the author.

Table 1.2 The distance between CRS stations and the Arctic region

Station	Minimum distance /km	Maximum distance /km
Guangzhou	5800	6500
Shanghai	4900	5700
Tianjin	4100	4800
Harbin	3100	4000

Source: Completed by the author.

Shortwave communication equipments in ships : transmit power is 150W and 250W, antennas are whip antenna and three wire antenna, antenna gain demonstrated by 0dB.Transmit power base transmitting equipment for general 5kW and 10kW .

1.5 Actual sailing records

Since 2013,YONGSHENG, the first Chinese merchant ship owned by COSCOL completed a voyage via Northeast route, and in 2015 it made a successful sailing via the same route that also created the new round-trip line between China and Europe, China has had 9 ships sailing through the Arctic route successfully until June,2017.It is visible that China has put efforts in the Arctic navigation with great development ambitions. The sailing conditions are shown in Table 1.3.

Table 1.3 Actual sailing records of China ships sailing through Arctic route

No.	Year	Name	Route	Cargo	departure/destination	Distance/n mile	Saving distance/n mile
1	2013	YONGSHENG (To west)	Far East-Europe	Steels, equipment	Taicang /Rotterdam	7931	2780
2	2015	YONGSHENG (To west)	Far East-Europe	Steels, equipment	Jiangyin/ Sweden	8221	3500
3	2015	YONGSHENG (To east)	Europe -Far East	Minerals, Steel pipe	Hamburg/ Tianjin	8403	3500
4	2016	YONGSHENG (To west)	Far East-Europe	Wind power equipment	Tianjin/ UK	8106	3000
5		XIA ZHIYUAN6 (To west)	Europe -Far East	YAMAL Project module	Tianjin/ Sabetta	6097	7550
6		TIANXI (To east)	Northern Europe -Far East	Paper	Finland/ Dalian	8552	3720
7		XIANG HEKOU (To east)	Northern Europe -Far East	Ballast navigation	Sabetta/ Qingdao	5912	7455
8		XIANG YUNKOU (To west)	Far East-Northern Europe	YAMAL Project module	Qingdao/ Sabetta	5912	7455
9		YONGSHENG (To east)	Europe -Far East	Minerals	UK/ Dalian	8012	2903

Source: Cai Meijiang, *Exploration and practice of Northeast Arctic channel navigation in recent three years*, World Shipping, 03, 2017, p15.16

Chapter 2

The Relationship between Ionospheric Characteristics and Short-wave Communication

2.1 Distribution of the ionosphere in the Arctic region

Due to the high-energy electromagnetic radiation, cosmic rays and other effects on the upper atmosphere of earth, the atmosphere of molecular ionization occurs, resulting in a large number of free electrons, ions and neutral molecules. As plasma region, the formation of the ionosphere, the ionospheric height is about 60~1000km. Atmosphere of earth basically has layered structure by gravity, the ionosphere, the physical and chemical changes with solar radiation and particle radiation and magnetic layer disturbance, relationship of the earth's magnetic field is not the same, resulting in electric generation rate maxima at several heights. The distribution of electron concentration is not gravity diffusion balance at a certain height, there are several peak electron concentration, the formation of several partitions.

In general, the ionosphere is divided into four regions according to the peak height of electron concentration: D, E, F, and above the upper (upper ionosphere). The model of short-wave communication is commonly considered as the lower ionosphere D, E, F. The time variation of each layer mainly depends on the amount of sunlight the solar zenith angle relationship.

The zonal variation of the ionosphere is the most obvious in the F2 layer. The most prominent is the mid latitude trough the equatorial ionospheric anomalies in the F2 + 20 degrees latitude layer electron density hump structure and night auroral boundary of the equator to 2 degrees ~10 degrees, namely the night in the geomagnetic latitude 50 degrees ~70 degrees F2 the maximum height of any height above the minimum value can be. The electron concentration observation to change their latitude to constitute the boundary of the low latitude-mid latitude and mid latitude - polar ionosphere.

The short-wave communication link between China and the Arctic, which is studied in this paper, spans 25 degrees to 78 degrees in latitude, and the reflection area of short-wave signals is between 33 and 70 degrees latitude. Therefore, short-wave communication needs to pass through the mid latitude trough region at night, but the influence of equatorial anomaly should not be taken into account during the daytime.

The critical frequency of the F2 layer foF2 ,which determines the communication frequency of short-wave communication, is the most important ionospheric parameters. Prediction and measurement of IRI value of foF2 model of both Svalbard and Zhongshan Station are better in summer than other seasons. This may be because the daily variation of IRI model is mainly based on the observation of the mid latitude and lower latitude.

Es is an inhomogeneous structure in E area. It is almost the same height as the regular E layer. Generally, it is 90-120km high from the ground, and the thickness is generally several hundred meters to 2 kilometers. The horizontal scale is 10-1000km. The critical frequency of the Es layer is higher, sometimes several times higher than the critical frequency of the same highly regular E layer.

Since the scattering of ionosphere signals is homogeneity, the echo pulse reflected from the F2 layer is 10 times wider than the transmitted pulse, which is called ionospheric spreading F (SF). The extended F layer occurrs mainly in the high latitude and equatorial latitudes, high latitude, high incidence at night. The extended F layer mainly affects the digital communication, which results in intersymbol interference and increasing bit error rate.

2.2 The influence of solar activity on the polar ionosphere

2.2.1 Sunspot. The important parameters that reflect sunspot influence are sunspot number, which indicates that solar radiation is enhanced and ion radiation can increase the ability of ionosphere to reflect short wave signals. The sunspot numbers are different every day, but the activity is consistent within the 11 year cycle. Sunspot numbers varied within the range of 0 to 200 over the 11 year cycle.

2.2.2 Solar flares. Solar flares give off incredibly large amounts of ions and very wide spectrum of electromagnetic energy. Flares usually appear near sunspots and last 1~2 minutes. Depending on the amount of X rays produced, the flare is divided into X, C and M. The flare has serious impact on the transmission of shortwave signals. Short wave communication, broadcasting and detection are interrupted by large areas or seriously disturbed for a long time when it occurs.

2.2.3 Coronal mass ejections. The high density plasma is 500km/s, equal to a small flare. During a high energy flare, more than half of the total energy may be related to mass ejections and shock waves, and the triggering relationship between flares and CME remains to be clarified. Recently, coronal mass ejection is the main form of energy background solar wind disturbances into the interplanetary space into the transient to the quality and form of a magnetic field; high energy CME drive interplanetary shock, while the high-energy particle acceleration.

The solar eruption output electromagnetic radiation, energetic particles and high-speed plasma, if arriving on earth, will lead to a series of strong disturbance on space, resulting in different degrees of damage to the system of space and ground, the phenomenon colloquially known as "solar storm". In strong solar eruptions, three forms of energy appear simultaneously, but the time they reach the earth varies with the ionosphere.

2.3 Comparison of polar communications and conventional (non polar) communications

The main differences between the two are as follows.

2.3.1 Aurora absorption: polar communication links pass through Polar Regions, increasing the possibility of aurora absorption relative to non polar communication links.

2.3.2 Polar cap absorption: The solar proton event caused by ionization of the polar ionosphere enhancement increases the electron density, and results in higher short-wave absorption, seriously affecting the communication.

2.3.3 Middle latitude trough: The communication link of the extreme region in China needs to pass through the middle latitude trough area at night. Because of the lower critical frequency of the mid latitude trough, the communication frequency of polar communication link is lower.

2.3.4 Extended F layer: It often occurs in the aurora oval region, so that the communication link Doppler extending across the polar region increases, mainly affecting the digital communications, causing intersymbol interference and increasing the bit error rate.

2.4 High latitude ionospheric channel and its influence on short-wave communication performance

The quality of short-wave communication is greatly affected by delay spread, Doppler frequency shift and Doppler spread. For the mid latitude region, the ionosphere is relatively stable, and the received signal usually experiences slow fading, and the transmission mode is constant and predictable. At this point, the information can be transmitted at a high rate (such as 4800bps). While in high latitudes, especially the auroral and polar cap area, severe ionospheric disturbances can lead to large Doppler spread, increasing delay spread. In this case, in order to reduce the influence of ionospheric channel for communication, we need to design the modem carefully, to select the best working frequency and the optimal transmission rate, so we need a quantitative description of the high latitude link Doppler and multipath effect. For this reason, the United Kingdom, Canada, Norway and Sweden set up DAMSON (Doppler and Multipath sounding Network) system together, which is used to assess high latitude ionospheric channel characteristics.

DAMSON system is used to obtain the multipath propagation of Doppler shift and

Doppler spread, signal-to-noise ratio and other parameters in multi frequency point pre-selected , using pulse compression technology (frequency range 2MHz ~ 22MHz) on real-time channel scattering function measurement. The multipath propagation refers to the first mode of transmission of multipath energy corresponding to 80% rise along with the last 80% corresponding mode of transmission energy decreased along the delay. Doppler spread is defined as complex Doppler spread ,which is assumed as Gauss type synthesis by Doppler propagation, that is determined by the mean measured (Doppler shift) and standard deviation (Doppler expansion); then superpose all power transmission mode spectrum to gain superposition synthesis power spectrum, then define the energy corresponding to the Doppler frequency shift of 80% expansion for the synthesis of Doppler, synthesis of power spectrum is defined as follows:

$$P(x) = \sum_i \frac{h_i}{\sigma_i \sqrt{2\pi}} \exp\left[-\frac{1}{2} \left(\frac{x-\mu_i}{\sigma_i} \right)^2 \right]$$

X is the frequency, h_i is the peak power for the number i propagation mode, u_i is the mean frequency of the number i propagation mode power spectrum, σ_i is the corresponding standard deviation.

The 4 links stations of the system are focused on the observation of a large number of tests on the Scandinavia Peninsula respectively. The transmit point Svalbard (78.06 ~ N, 13.63 ~ E), Harstad (68.48 ~ N, 16.30 ~ E) and received point Tuentangen (59.94 N, 11.09 E), Kiruna (67.84 ~ N, 20.40 ~ E). The transmitting power of Svalbard point is 250W, transmitting antenna is rhombic antenna; transmitting power of Harstad is 250W, transmitting antenna is horizontal broadband dipole antenna, and the receiving point Tuentangen and Kiruna use 80 meters oblique V antenna and dipole antenna for receiving signal cable respectively. The distance between the 4 transmission links is shown in Table 2.1, and the distribution is shown in Figure 2.1.

Table 2.1 Distance of 4 links stations

Name of link	Distance/km
Svalbard—Tuentangen	2019
Svalbard—Kiruna	1158
Harstad—Tuentangen	1019
Harstad—Kiruna	194

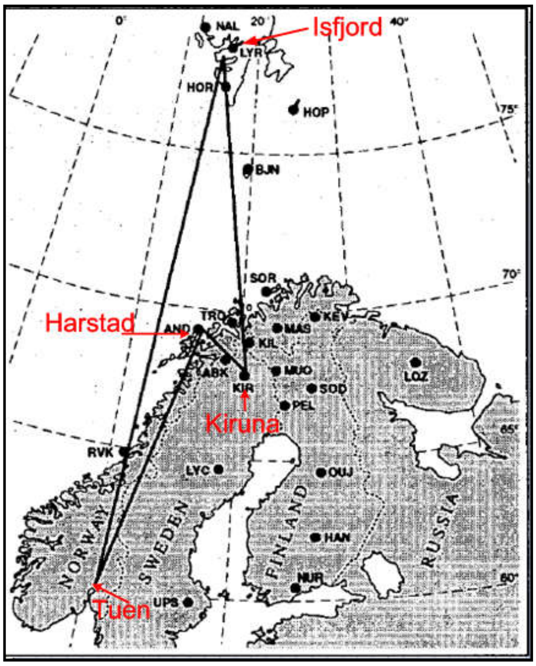

Figure 2.1 Distribution of 4 links

We need to focus on the effects of 3 parameters: multipath propagation, Doppler spread and signal-to-noise ratio, when designing a high latitude short-wave communication system.

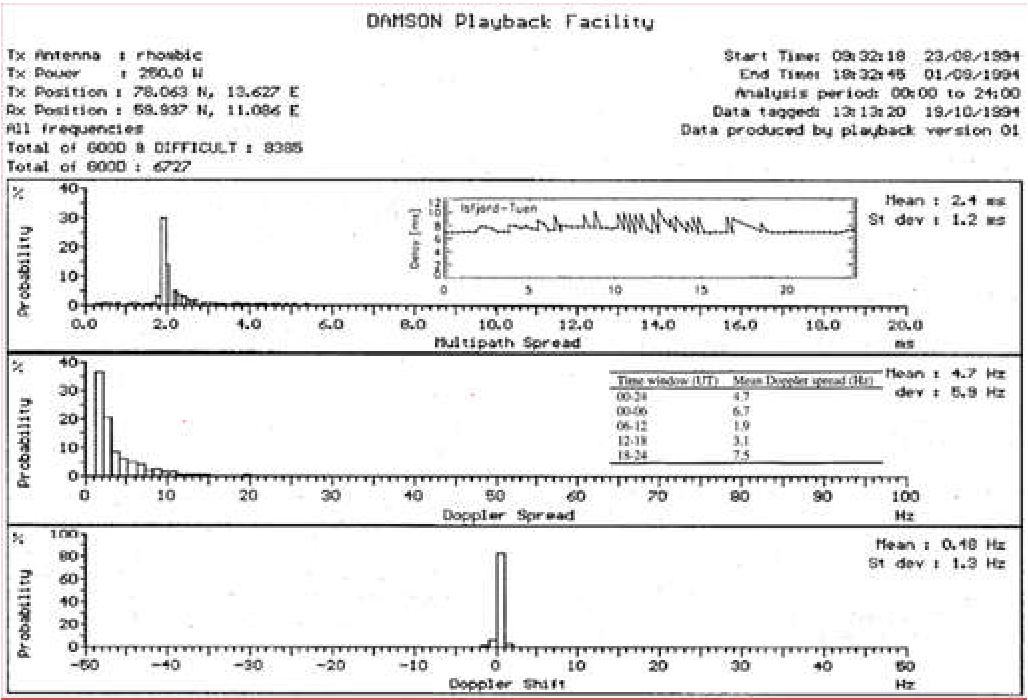

Figure 2.2 Histogram of DASON system analysis examples

Figure 2.2 shows the multipath fading, Doppler spread and Doppler shift statistics of Aug.23th,1994 to Sep 1st,1994 over a total of 10 days (Svalbard - Tuentangen link).

We can see that from the diagram, the Doppler broadening of ionospheric disturbances can reach about 20Hz (the normal Doppler broadening is less than that), and the Doppler broadening averages is 4.7Hz, and the standard deviation is 5.9Hz. The average Doppler frequency shift is 0.48Hz.

Usually, in order to ensure system availability is more than 95%, we need to make sure that short-wave modems can tolerate the maximum Doppler spread and multi-path propagation, which means the transmission range of Doppler spread and multi-path propagation in 95% time.

On the other hand, the current waveforms of commercial 3kHz high frequency modem on the market mostly follow the military standard MILSTD188110A/B and the North Atlantic Treaty Organization STANAG 4539/4415. These standards evaluate the performance of modems at different transmission rates, such as the minimum performance requirements for different rate modems in a single tone serial system, as shown in Table 2.2.

Table 2.2 Minimum performance requirements for different rate modems in US standard 110A

Baud Rate	Multipath Dispersion /ms	SNR/dB	Error Rate
4800	-	17	1.0E-3
4800	2	27	1.0E-3
2400	-	10	1.0E-5
2400	2	18	1.0E-5
2400	2	30	1.0E-3
2400	5	30	1.0E-5
1200	2	11	1.0E-5
600	2	7	1.0E-5
300	5	7	1.0E-5
150	5	5	1.0E-5
75	5	2	1.0E-5

According to the DAMSON system multipath expansion and Doppler expansion statistical results, we can draw the following conclusions:

2.4.1 In order to ensure the error rate of high latitude short-wave communication systems is less than 95%, we could only use low rate robust communication systems, such as 75 BPs.

2.4.2 Tt is necessary to select the transmission rate according to the ionospheric state because in specific links and some time, the optimal transmission rate can be far greater than 75bps, such as HT 1-7 ,which can allow the transmission link time at the rate of 2400bps.

2.4.3 Frequency selection is very essential for improving the performance of the system, because the optimum transmission rate is different in some specific links and different frequencies.

Chapter 3

The frequency of Arctic short-wave communication

3.1 Basic study method

The basic MUF and LUF are the two primary concerns of frequency selection of short-wave communication. The ionospheric research results show that the rule of polar ionospheric accord with ionospheric variation. IRI model calculation results and the actual observation value are consistent, so the demonstration of basic MUF and the LUF of the polar ionosphere short-wave communication link could use IRI model.

The basic MUF uses the calculation of the method given by the International Telecommunications Union's Rec. ITU-R P.1240 recommendation(ITU,2015). LUF uses the calculation of the method given in Rec ITU-R P.373(ITU,2013).

LUF relies on transmitter power, as well as path loss (frequency, season and geographical location, etc.) and noise levels (main frequency and reception location) and so on. Field strength calculations are calculated in accordance with the ITU-R P.533(ITU,2015) method. Polar absorption is considered in the ITU-R P.533 report, and polar absorption is related to geomagnetic latitude and local time.

The noise power is calculated according to the method given by Rec.ITU-R P.372 ((ITU,2016)) to calculate the mean monthly value of the atmospheric noise power.

3.2 MUF

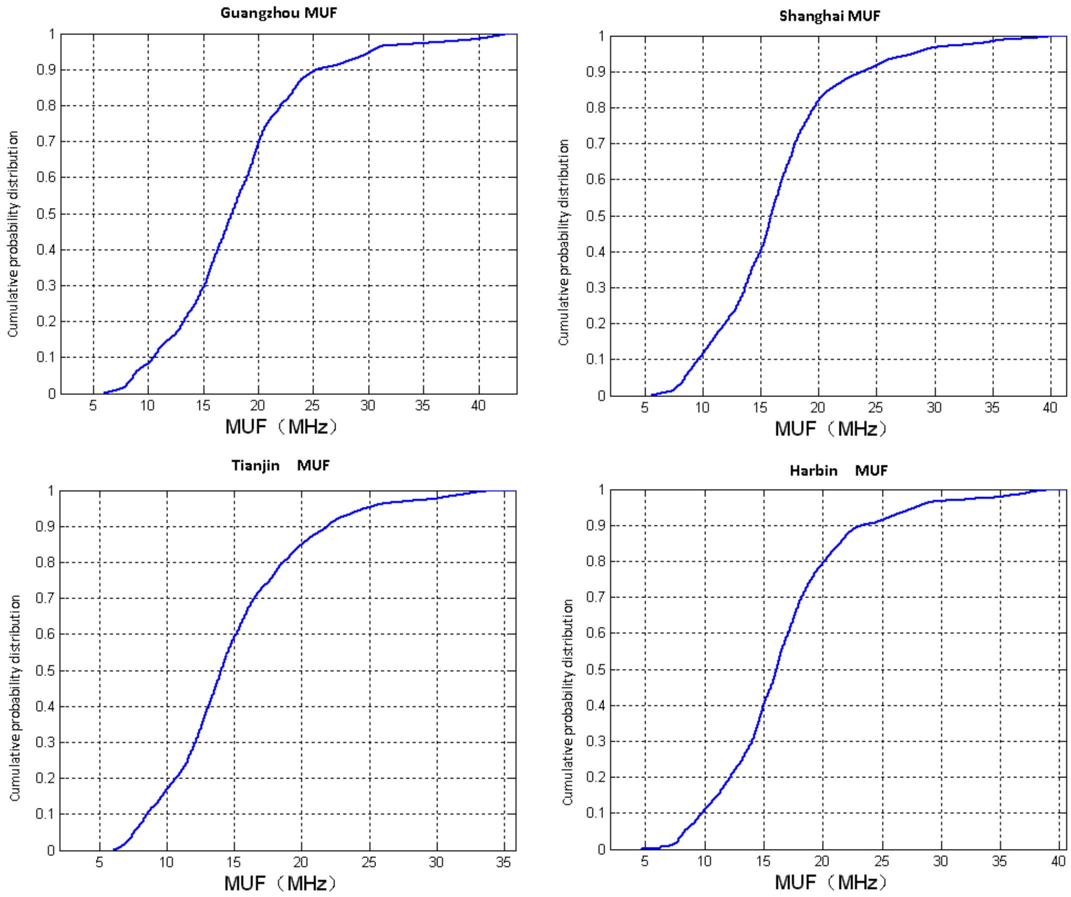

Figure3.1 MUF cumulative probability distribution

Source: Completed by the author.

From the cumulative distribution of each CRS, as shown in Figure 3.1, we can see that Guangzhou, Shanghai and Harbin are concentrated in 10-25MHz (80%), 5-10MHz and greater than 25MHz account for 10% . Tianjin is concentrated in 8-20 MHz (80%), 20MHz above only accounts for 15%, MUF is relatively low.

Based on the cumulative distribution of MUF and the MUF distribution under different solar activity conditions of different stations, the Maximum available frequency band for four stations are shown in Table 3.1.

Table 3.1 Maximum available frequency band for four stations

CRS station	solar activity		
	low	middle	high
Guangzhou	5.96-23.96	7.87-30.00	9.94-30.00
Shanghai	5.54-22.85	7.79-29.99	8.60-30.00
Tianjin	6.00-21.80	7.14-26.89	8.06-30.00

Harbin	4.70-23.05	6.55-29.66	10.17-29.99

Source: Completed by the author.

3.3 LUF for ship to shore

Because the transmitting and receiving is unequal,and the receiver noise level is different, so we calculate the lowest usable frequency band for both ship to shore and shore to ship respectively,according to the different environmental noise level .

Short-wave communication frequency is mainly according to the highest available frequency, lowest usable frequency is only as a reference value. Ships receiving ground stations are only corresponding to different transmit powers with different solar activities that the suburbs under the environment of the lowest available frequency range. The usable frequency bands of LUF are given in the form of the LUF range of the different environmental noise levels of the receiving points, and the LUF in this section is calculated according to the required SNR of the terminal service for 6dB.

In this section, we give the cumulative distribution and the total LUF accumulation map of 150W of each station, the transmit antenna 0dB, the receiving antenna and the 15dB receiving point as the suburban level, and the LUF of different solar activity.

The cumulative distribution is given for the low, middle and high solar activity years and the noise environment of suburban respectively, shown as Table 3.2 to 3.9

Table 3.2 Guangzhou Station receiving_ LUF

Receiving antenna gain(dB)	Transmitting power(w)	Solar activity		
		Low	Middle	High
0	150	10.20-23.00	9.50-27.30	9.80-29.30
	250	7.20-23.30	7.50-26.80	7.90-26.40
15	150	2.20-14.50	2.50-18.10	3.1-19.50
	250	2.00-13.60	2.20-18.10	2.00-19.30

Source: Completed by the author.

Table 3.3 Shanghai Station receiving _ LUF

Receiving antenna gain(dB)	Transmitting power(w)	Solar activity		
		Low	Middle	High
0	150	6.20-21.30	6.60-23.50	7.20-26.80
	250	4.60-19.10	5.00-21.20	5.60-26.10
15	150	2.00-15.60	2.00-16.90	2.40-17.30
	250	2.00-15.10	2.00-16.90	2.00-17.20

Source: Completed by the author.

Table 3.4 Tianjin Station receiving _ LUF

Receiving antenna gain(dB)	Transmitting power(w)	Solar activity		
		Low	Middle	High
0	150	3.90-20.20	4.30-24.70	4.90-24.40
	250	3.00-18.50	3.30-19.50	3.80-22.80
15	150	2.00-13.60	2.00-13.90	2.00-14.50
	250	2.00-13.50	2.00-13.90	2.00-14.10

Source: Completed by the author.

Table 3.5 Harbin Station receiving _ LUF

Receiving antenna gain(dB)	Transmitting power(w)	Solar activity		
		Low	Middle	High
0	150	2.00-17.20	2.10-19.40	2.50-20.50
	250	2.00-15.90	2.00-17.90	2.00-19.90
15	150	2.00-11.00	2.00-11.10	2.00-11.20
	250	2.00-11.00	2.00-11.10	2.00-11.20

Source: Completed by the author.

3.4 LUF for shore to ship

The electromagnetic environment of shipboard communication equipment is affected by several influence factors. Because the man-made noise is relatively small, so this section only considers the natural noise of the receiving point, the same as the village level.

Assuming that the SNR required by receiver in this section is 6dB, transmit power is 5kW and transmitting antenna is 10dB, receiving antenna is 0dB. Noise level of Ship receiving point is village level .Then give the LUF distribution of four CRS stations under different solar activities, as is shown in table 3.6 to 3.9.

Table 3.6 Guangzhou Station transmitting _ LUF

Transmitting power(kw)	Antenna gain(dB)	Solar activity		
		Low	Middle	High
5	10	2.00-13.00	2.00-14.00	2.00-17.00
	15	2.00-12.00	2.00-13.00	2.00-16.00
10	10	2.00-12.00	2.00-13.00	2.00-16.00
	15	2.00-11.00	2.00-12.00	2.00-15.00

Source: Completed by the author.

Table 3.7 Shanghai Station transmitting _ LUF

Transmitting power(kw)	Antenna gain(dB)	Solar activity		
		Low	Middle	High
5kw	10	2.00-12.00	2.00-13.00	2.00-15.00

	15	2.00-12.00	2.00-12.00	2.00-14.00
10kw	10	2.00-12.00	2.00-12.00	2.00-15.00
	15	2.00-12.00	2.00-12.00	2.00-14.00

Source: Completed by the author.

Table 3.8 Tianjin Station transmitting _ LUF

Transmitting power(kw)	Antenna gain(dB)	Solar activity		
		Low	Middle	High
5	10	2.00-10.00	2.00-11.00	2.00-14.00
	15	2.00-10.00	2.00-10.00	2.00-12.00
10	10	2.00-10.00	2.00-11.00	2.00-13.00
	15	2.00-10.00	2.00-10.00	2.00-12.00

Source: Completed by the author.

Table 3.9 Harbin Station transmitting _ LUF

Transmitting power(kw)	Antenna gain(dB)	Solar activity		
		Low	Middle	High
5	10	2.00-8.00	2.00-9.00	2.00-11.00
	15	2.00-8.00	2.00-8.00	2.00-10.00
10	10	2.00-8.00	2.00-9.00	2.00-10.00
	15	2.00-8.00	2.00-8.00	2.00-10.00

Source: Completed by the author.

3.5 Summary

Communication frequency selection is generally between MUF and LUF frequencies, but low frequency absorption is relatively strong, therefore, short-wave communication frequency should be determined according to MUF. You can see from the contents of the sections 3.1 to 3.4:

(1) MUF increases while solar activity increases.

(2) The diurnal variation of MUF in 6-8 months is not large, and the diurnal variation is greater in the 9-11 months.

(3) MUF of Guangzhou Station, Shanghai Station and Harbin Station are higher than Tianjin Station.

(4) The basic MUF of Guangzhou is the highest; the MUF of Tianjin is relatively low.

(5) Considering the coverage period of the solar cycle, the usable frequency range of each station is given. The frequency range is also the frequency range of the antenna

design, as shown in Table 3.10.

Table 3.10 Usable frequency range of four stations

	Guangzhou	Shanghai	Tianjin	Harbin
Frequency range (MHz)	5.96-30.0	5.54-30.00	6.00-30.000	4.70-30.00

Source: Completed by the author.

Chapter 4

Antenna parameter study of CRS stations

4.1 Basic study method

The study of antenna parameter in shore-based communications is mainly on two aspects: antenna elevation range and gain.

(1) Rated minimum transmit power

$$P_{t\min} = P_{r\min} + L_s \text{(dbW)}$$

P_{rmin} : The minimum received power required by the receiving point

$$P_{r\min} = N + P_n \text{(dbW)}$$

N： SNR required by the receiving point

P_n ： Noise power of receiving point

(2) $$P_n = F_a + 10\lg b(c/s) - 204 \qquad \text{(dbW)}$$

$$F_a = F_{am} + D_u + \sqrt{\sigma_{Fam}{}^2 + \sigma_{Du}{}^2} \qquad \text{(dbTKb)}$$

F_a ： Maximum noise power occurs in 90% of time

F_{am}, D_u: parameter of noise, calculated as World noise map Report published by ITU

(3) System loss

$$L_s = Pt - \Pr = L_{bf} + L_i + L_m + L_g + L_h + L_z - (G_t + G_r)$$

$$P_{t\min} + G_t = P_{r\min} + L_{bf} + L_i + L_m + L_g + L_h + L_z - G_r$$

Path loss calculations is calculated in accordance with the Rec.ITU-R P.533(ITU,2015) method, and polar absorption has been taken into account in the ITU533 report. The noise power is calculated according to the method given by Rec.ITU-R P.372 (ITU,2016) to calculate the mean monthly value of the atmospheric noise power. From the conclusion of the polar ionosphere, it can be seen that in the region , the abnormal ionospheric events (polar cap absorption, sudden ionospheric disturbance and ionospheric storm) have great influence on the short-wave communication, but the frequency is low, for it to a small probability event, includes:

(1) Polar cap absorption occurs less frequently, with an average of 7.5 times per year, average absorption is above 6dB, up to 26dB, so in order to improve the system, the allowance of 6dB is to be increased and the common absorption in the antenna again argument is to be considered..

(2) The sudden disturbance of the ionosphere has a great influence on short-wave communication, which can cause short-wave communication to break suddenly (absorb more), but the duration is short, so it will not be considered in the process of system design.

Shore based transmitter power for 5kW and 10kW, the antenna gain can be given according to the statistics of the PG values.

The rate of communication is the result of the statistical result under the condition that the SNR of the best frequency is greater than the required SNR at a given time within 2-30MHz, without considering whether the frequency interferens or not. In practice, the frequency cannot be changed in time according to the ionospheric changes. For example, according to the mode of a daily frequency and a night frequency, the rate of communication will be reduced.

4.2 Antenna elevation range of CRS

The calculate method has referred to Rec.ITU-R P.533(ITU,2015).

$$\Delta = \arctan\left[\cot\frac{d}{2R_0} - \frac{R_0}{R_0 + h_r}\operatorname{cos}ec\,\frac{d}{2R_0}\right]$$

d：Hop distance of minimum hop mode,d=D/n；

hr：Equivalent mirror height;

hr=110(for E layer mode),

hr is function of time, location, and hop distancetime point (for F2 layer mode)

x= foF2/ foE

$$H=\frac{1490}{M(3000)F_2 + \Delta M} - 316$$

$$\Delta M = \frac{0.18}{y-1.4} + \frac{0.096(R_{12}-25)}{150}$$

y= x or 1.8(the bigger one)

The antenna elevation range of CRS can be shown in Tables 4.1 and 4.2, according to the calculation method mentioned above.

Table 4.1 Antenna elevation range of CRS (Time)

Solar activity	Antenna elevation range (degree)			
	Guangzhou	Shanghai	Tianjin	Harbin
Low	3.00-36.27	4.00-38.24	7.06-42.95	3.00-37.13
Middle	3.00-37.67	4.62-42.67	7.30-46.11	3.00-41.70
High	3.33-43.19	5.45-45.07	8.37-51.11	3.00-44.24

Source: Completed by the author.

Table 4.2 Antenna elevation range of CRS (probability)

Probability	Antenna elevation range (degree)			
	Guangzhou	Shanghai	Tianjin	Harbin
100%	3.0-43.19	4.0-45.07	7.06-51.11	3.00-44.24
99%	3.0-35.0	4.0-37.0	7.06-41.0	3.00-35.0
97%	3.0-33.0	4.0-35.0	7.06-37.0	3.00-31.0
95%	3.0-30.0	4.0-31.0	7.06-35.0	3.00-29.0

Source: Completed by the author.

4.3 Antenna gain of CRS

Several aspects need to be considered in order to determine antenna gain for CRS.

(1) In order to cover the whole solar cycle, the antenna gain should meet the requirements of low solar activity index.

(2) The ship's transmitting power is 150W and 250W, the receiving antenna of CRS is determined according to the minimum transmit power.

(3) Along with the development of modern industry, the electromagnetic environment of the CRS stations makes it difficult to reach the rural level, so the environmental level of stations' receiving points is considered by the suburbs.

According to the calculation results, the antenna gain of CRS is determined by comprehensive analysis, assuming the rate of communication is 75%.

Table 4.3 Receiving Antenna gain of CRS

Environment	SNR required by receiver(dB)	Antenna gain (dB)			
		Guangzhou	Shanghai	Tianjin	Harbin
village	6	13	11	11	9

Suburb	6	16	14	15	13

Source: Completed by the author.

Table 4.4 Transmitting Antenna gain of CRS

Environment	SNR required by receiver(dB)	Antenna gain (dB)			
		Guangzhou	Shanghai	Tianjin	Guangzhou
village	6	0	0	0	0
	15	3	2	3	2

Source: Completed by the author.

It is suggested that the gain of CRS station receiving antenna consider the corresponding antenna gain in the case of 75% rate of communication. Because the noise environment is selected artificially, the actual situation can be determined by measuring the noise, receiver noise, temporary design in accordance with the calculation of suburb level, four kinds of antenna according are recommended to the antenna gain result.

4.3.1 Receiving antenna

Given that antenna gain of Shanghai, Tianjin and Harbin is 9-15dB range, double log periodic antenna gain is 11-15dB, it is suggested that receiving antenna of Shanghai, Tianjin and Harbin could be double logarithmic antenna. Antenna gain of Guangzhou is 13-16 dB, fishbone antenna gain is 17dB, but the single piece of fishbone antenna azimuth coverage is about 20 degrees, so Guangzhou could pay 3 fishbone antennas as group. The recommendation is shown in Table 4.5.

Table 4.5 Receiving antenna of CRS

	Guangzhou	Shanghai	Tianjin	Harbin
Gain (dB)	13-16	11-14	11-15	9-13
Type	3 fishbone antennas as group	1 double logarithmic antenna		
	1 rotation log periodic antenna			

Source: Completed by the author.

4.3.2 Transmitting antenna

If the receiving environment for the noise is at village level, the ground antenna is 0dB, according to the results of the polar ionospheric research, considering the 6dB margin, in response to the solar proton event caused by the polar cap absorption, so the ground launching antenna is proposed to use a log periodic antenna. Because the gain of rotation log periodic antenna is almost the same as log periodic antenna, and it needs smaller area, more flexible (can turn to different direction), so that we suggest using rotating log periodic antenna as transmitting antenna.

Within the range of double logarithmic, combining fishbone antenna rotation and log periodic antenna can cover only 60 degrees, which can only meet the communication in the Bering Strait region, and cannot effectively cover the south of Russia's territorial waters, we suggest increasing the flexible high gain rotating log periodic antenna in sending and receiving stations, make sure that the single antenna direction can cover all directions.

The recommendation of antenna elevation range is shown as table 4.6.

Table 4.6 Antenna elevation range of CRS

Elevation probability	Elevation range (Unit:degree)			
	Guangzhou	Shanghai	Tianjin	Harbin
100%	3.0-43.19	4.0-45.07	7.06-51.11	3.00-44.24
99%	3.0-35.0	4.0-37.0	7.06-41.0	3.00-35.0
97%	3.0-33.0	4.0-35.0	7.06-37.0	3.00-31.0
95%	3.0-30.0	4.0-31.0	7.06-35.0	3.00-29.0

Source: Completed by the author.

Chapter 5

Analysis and comparison of advantages of the four coastal radio stations

5.1 Ship to shore

According to the calculation results, four ground stations are compared as following.

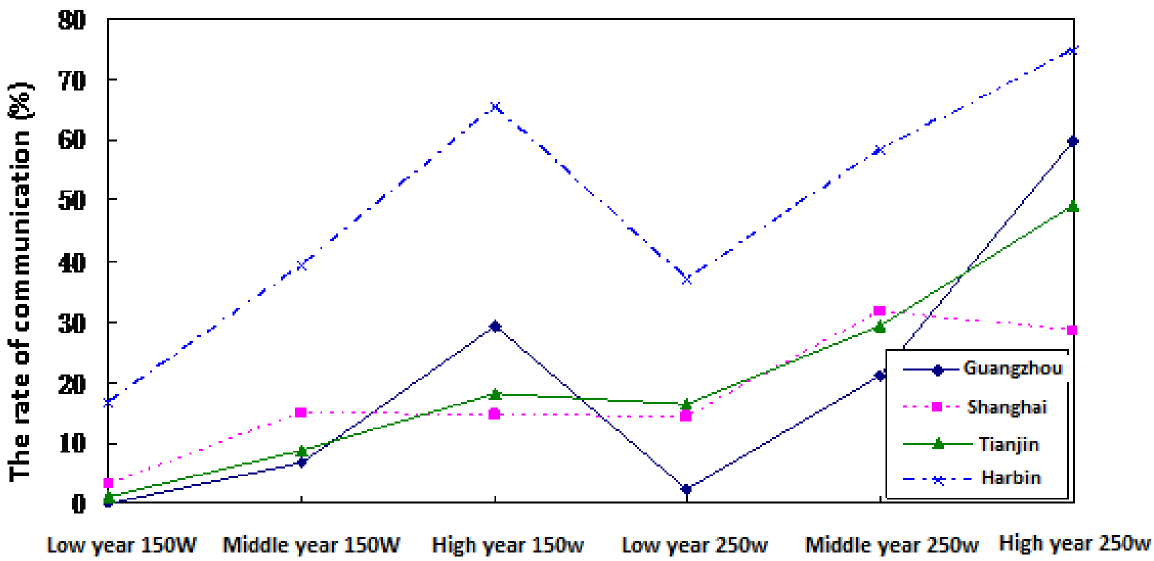

Figure 5.1 The rate of communication of CRS (Ship to shore, Suburb environment)

Source: Completed by the author.

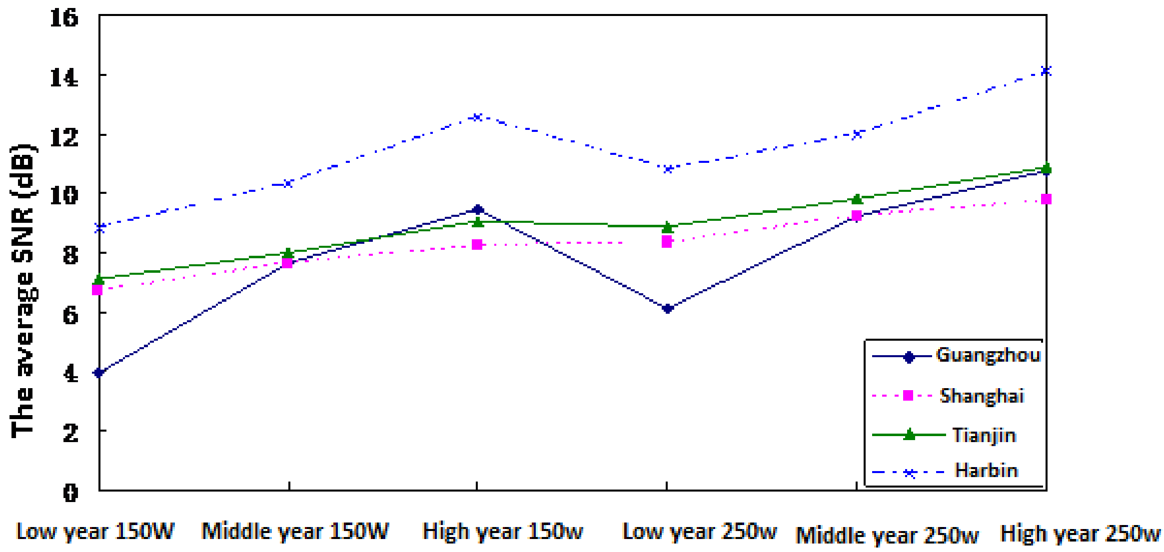

Figure 5.2 The average SNR of CRS (Ship to shore, Suburb environment)

Source: Completed by the author.

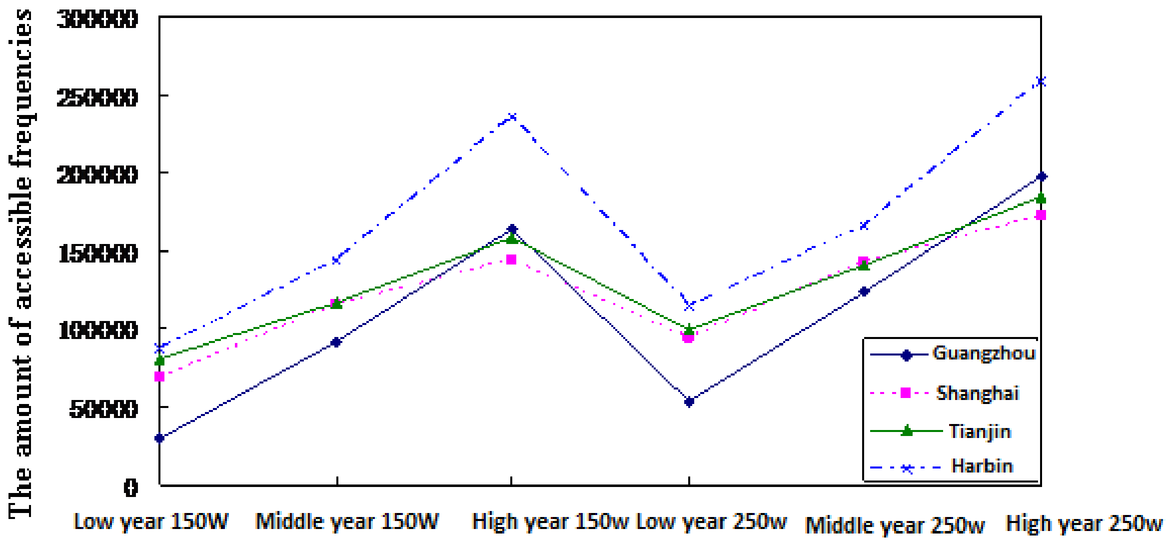

Figure 5.3 The amount of accessible frequencies of CRS (Ship to shore, Suburb environment)

Source: Completed by the author.

(1) Assuming the environmental types of the receiving points are the same, compared with the other three ground stations, the Harbin Station has higher rate of communication with average SNR and the amount of accessible frequencies.

(2) Assuming the environmental types of the receiving points are the same. As shown in Figure 5.1, the rate of communication of Guangzhou is higher than Shanghai and Tianjin, in the middle and the high age year of solar activity. Shanghai is higher than Tianjin and Guangzhou in low age year of solar activity.

(3) Assuming the environmental types of the receiving points are the same. As is shown in Figure 5.2, the average SNR of Tianjin is higher than Guangzhou and Shanghai in the low and middle age year of solar activity .Guangzhou is higher than Shanghai and Tianjin in high age year of solar activity.

(4) Assuming the environmental types of the receiving points are the same. As is shown in Figure 5.3, the amount of accessible frequencies of Tianjin is more than Shanghai, and Guangzhou is the lowest in low age year of solar activity. The amount of accessible frequencies of Guangzhou is more than Tianjin, and Shanghai is the lowest.

(5) The results of rural level calculations are higher than those in suburban areas.

5.2 Shore to ship

Comparing the results of the rate of communication, the SNR, the amount of accessible frequencies of the corresponding communication link for the ground stations, we conclude as following:

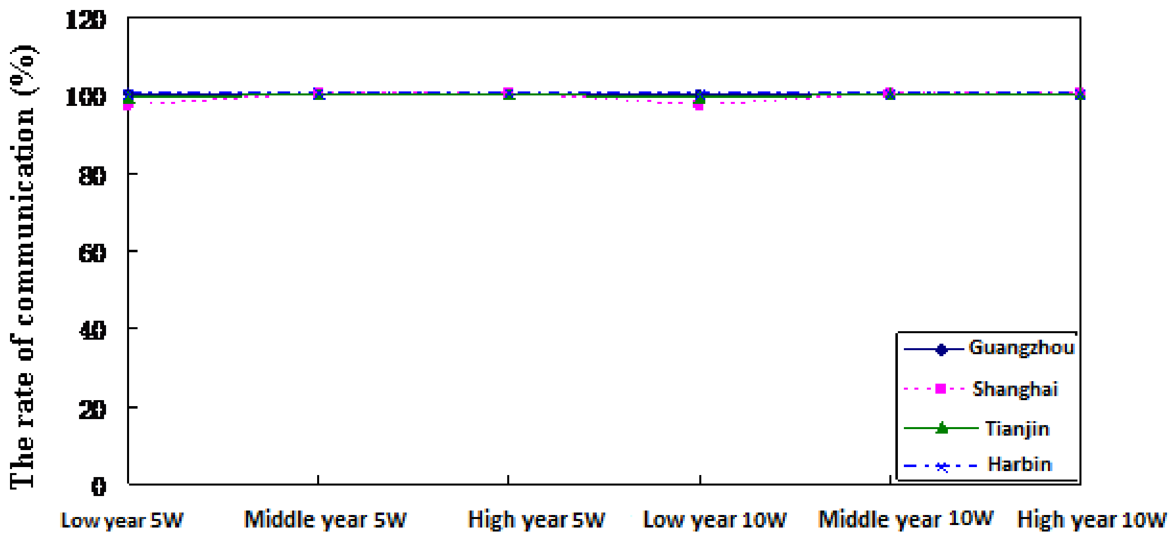

Figure 5.4 The rate of communication of CRS (Shore to ship, Village environment)

Source: Completed by the author.

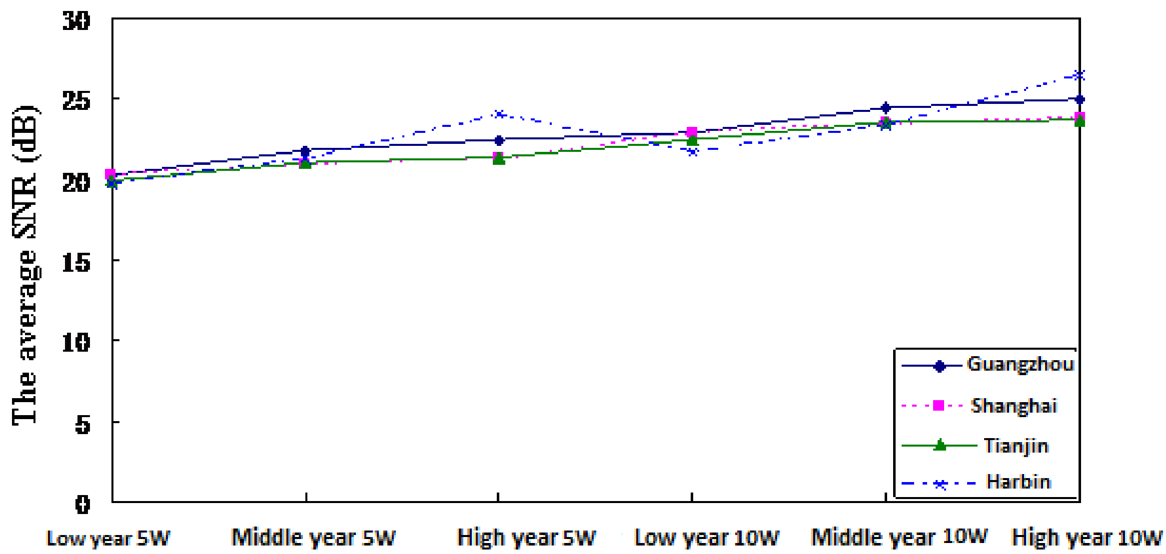

Figure 5.5 The average SNR of CRS (Shore to ship, village environment)

Source: Completed by the author.

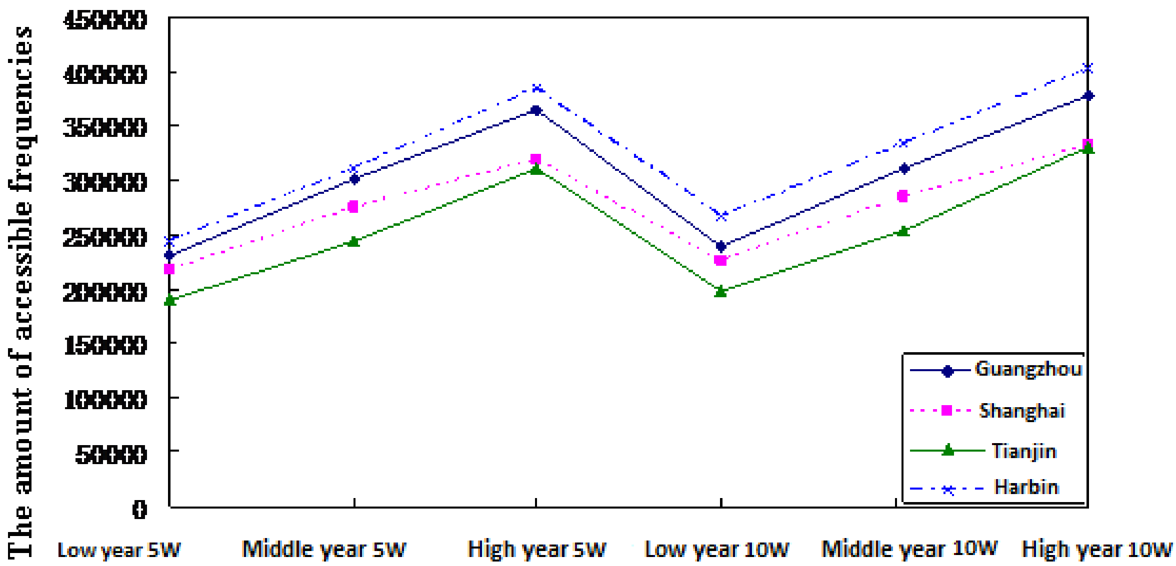

Figure 5.6 The amount of accessible frequencies of CRS (Shore to ship, village environment)

Source: Completed by the author.

(1) The four stations all have high rate of communication, and Shanghai is lower than the other three stations in low age year of solar activity.

(2) The average SNR of four stations are higher than 15dB, Shanghai is higher than other three stations in low age year of solar activity. Guangzhou is higher than other three stations in middle age year of solar activity. Harbin is higher than other three stations in high age year of solar activity.

(3) The amount of accessible frequencies of Harbin is more than that of other three stations.

5.3 Analysis of background radio noise intensity of 4 CRS Stations

The reception quality depends on the SNR of receiver in short-wave communication (signal in electric field strength /the local radio noise intensity ratio). Therefore, the local radio noise intensity level of the receiving station has an important restriction on the communication quality of the short-wave communication system.

5.3.1 Internal noise and external noise

The radio noise of receiving station can be divided into two kinds: internal noise and external noise according to the generated source. The radio noise generated within the receiving device is called internal noise. Compared with the internal noise, the natural radio noise originating from the surface, the earth, the atmosphere and the earth (the universe), and man-made radio noise are known as external noise.

5.3.2 Natural noise and man-made noise

Natural noise is caused by the electromagnetic process that exists objectively in nature and has no direct relation with human activity. This kind of radio noise can be divided into two kinds. The first class originated in the earth's atmosphere, usually called atmospheric radio noise; second originated from outside the earth, the sun and other stars, the Milky Way outer space, namely the radio radiation disturbance from outside the earth's atmosphere, usually called cosmic noise.

Natural radio noise is the basic element of the earth's radio noise environment". However, with the development of society and economy, more and more people are creating new elements in this environment. This is due to man-made noise caused by human activities. Human noise sources are mainly industrial, scientific, medical equipment, automotive ignition equipment, information technology equipment, power lines and electrified railways.

According to the source and nature of man-made noise, man-made noise environment categories can be divided into four categories, including: quiet rural, rural, suburban and industrial and commercial areas.

5.3.3 Comparison of 4 CRS Stations

Here we use the typical background conditions in the South China Sea, East China Sea and the North Sea as the data to calculate for CRS Stations.

The coast radio station radio background noise calculation is taken into account in two level environmental conditions: rural and suburban. And we consider the influence of atmospheric radio noise and cosmic noise and other factors on the environment of radio noise intensity.

Calculate each station in the summer, rural and suburban background conditions in different time (Beijing time: 00:00-04:00, 04:00-08:00, 08:00-12:00, 12:00-16:00, 16:00-20:00, 20:00-24:00) of integrated radio noise intensity with frequency.
Typical frequencies: 5MHz, 8MHz, 11MHz, and 14MHz.

The calculated results of integrated radio noise intensity with frequency in different rural and suburban background conditions in summer are shown in Figures 5.7 to 5.14 respectively.

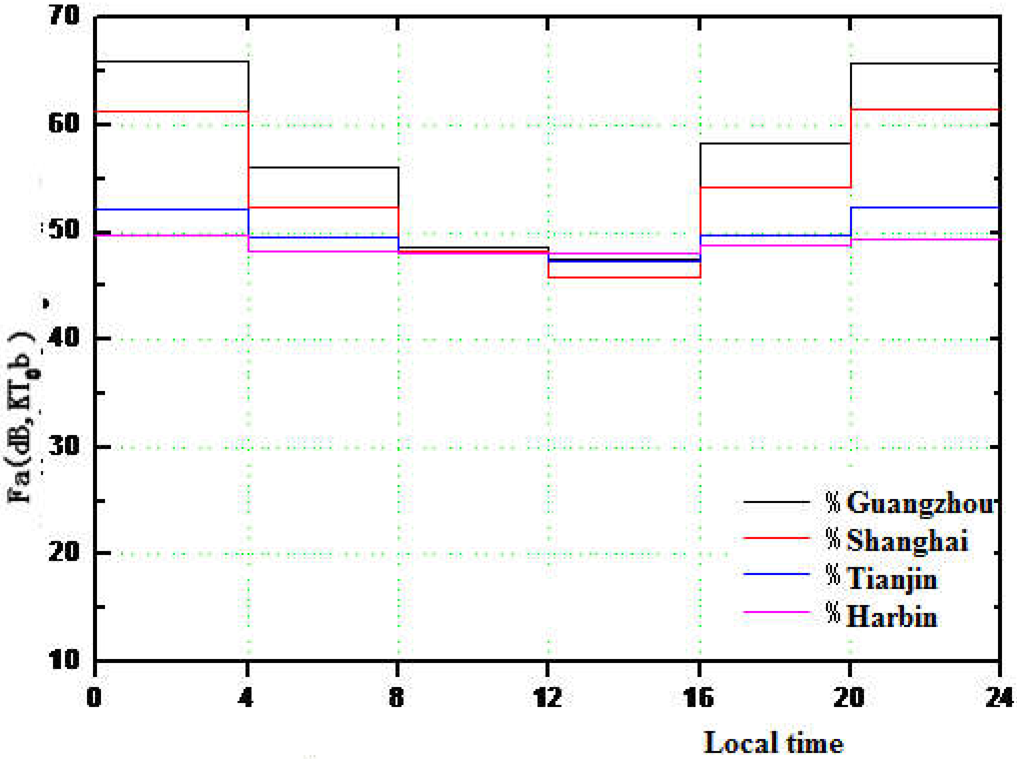

Figure 5.7 Background radio noise intensity (Rural, 5MHz)

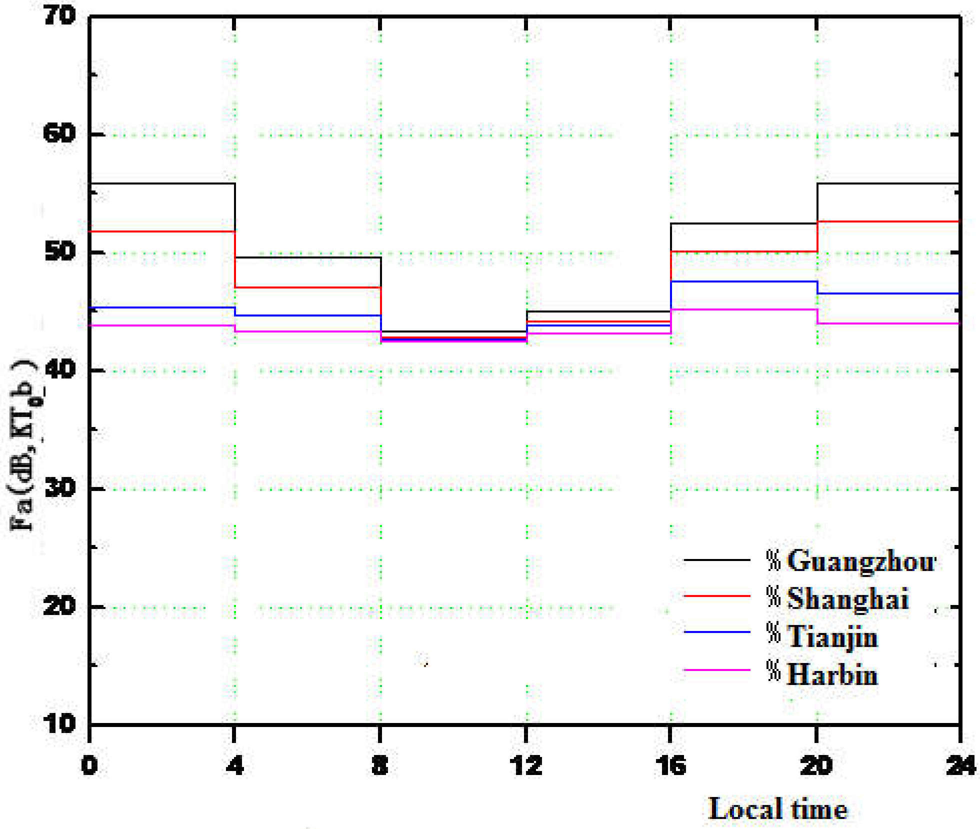

Figure 5.8 Background radio noise intensity (Rural, 8MHz)

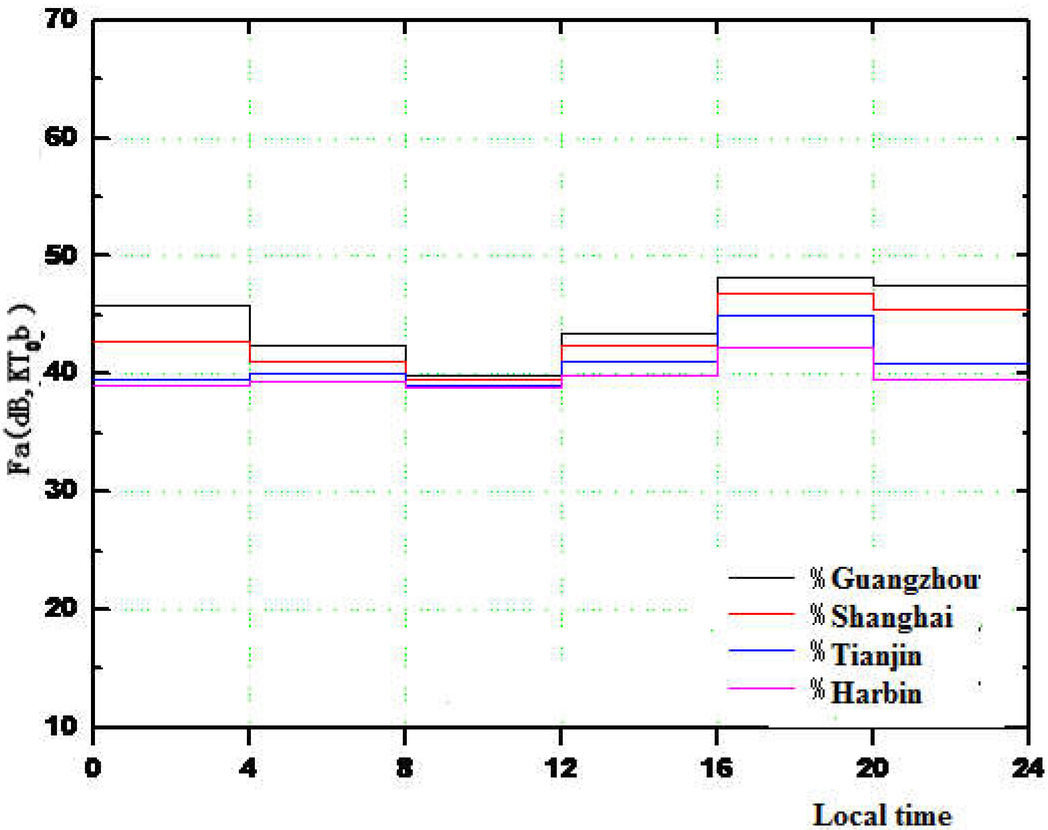

Figure 5.9 Background radio noise intensity (Rural, 11MHz)

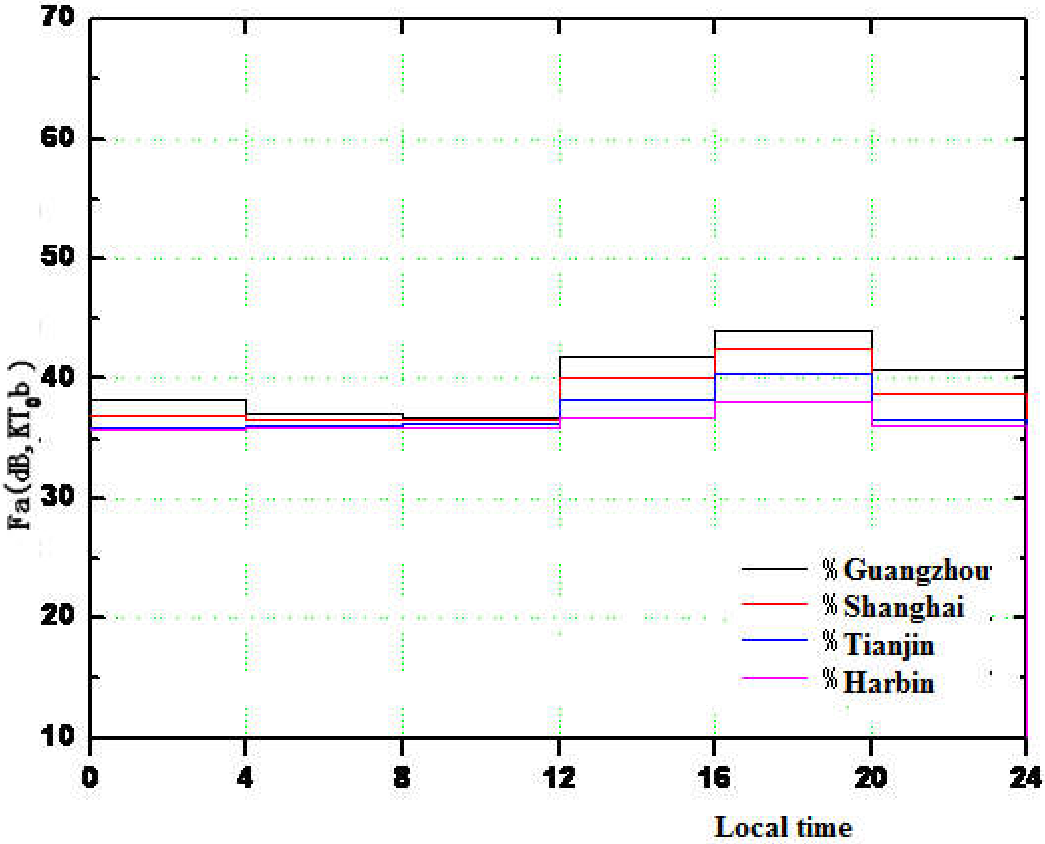

Figure 5.10 Background radio noise intensity (Rural, 14MHz)

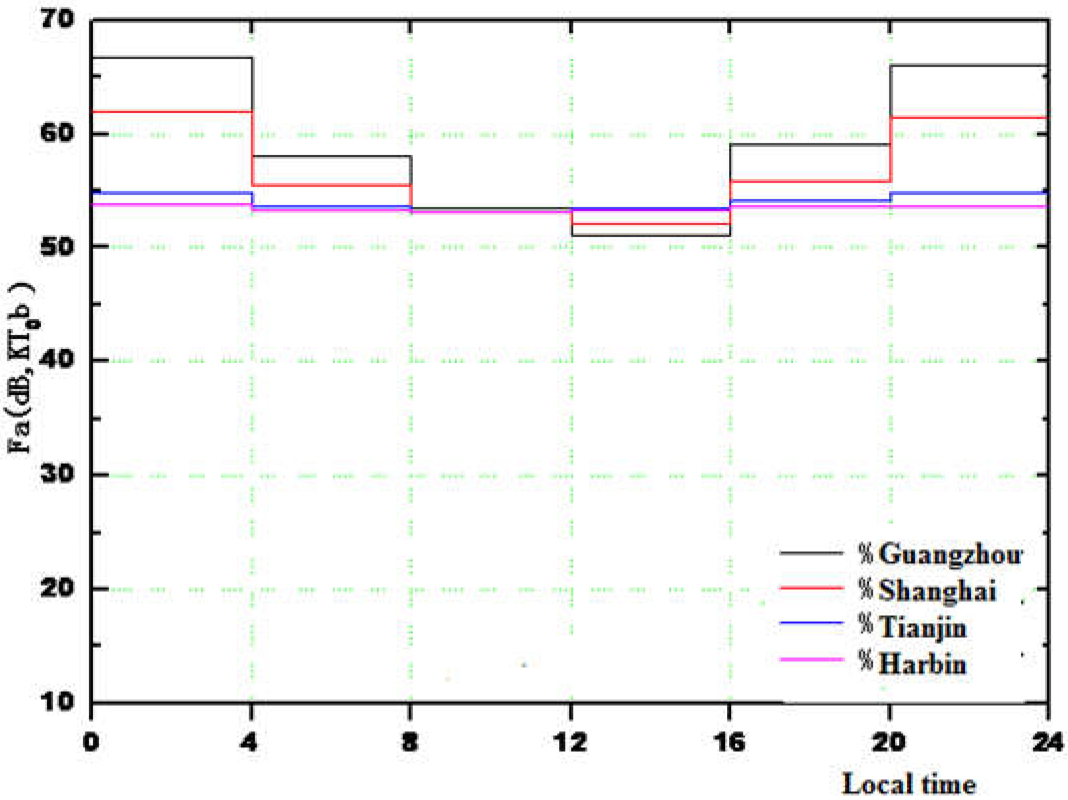

Figure 5.11 Background radio noise intensity (Suburban, 5MHz)

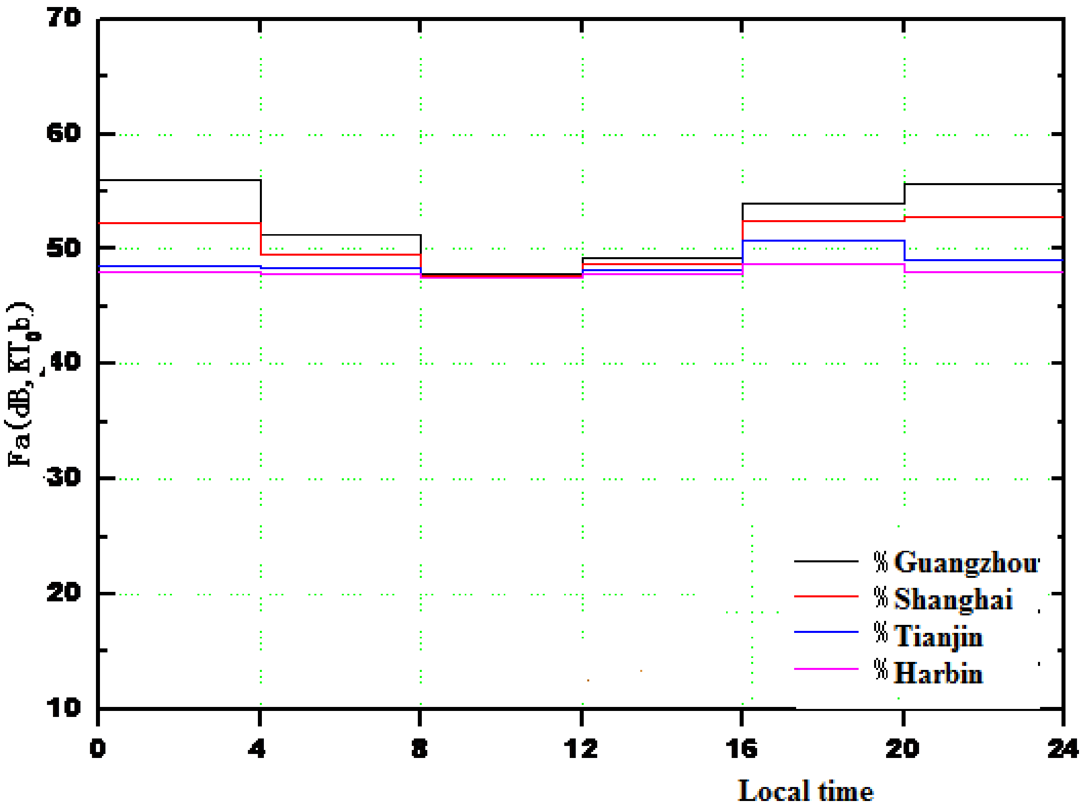

Figure 5.12 Background radio noise intensity (Suburban, 8MHz)

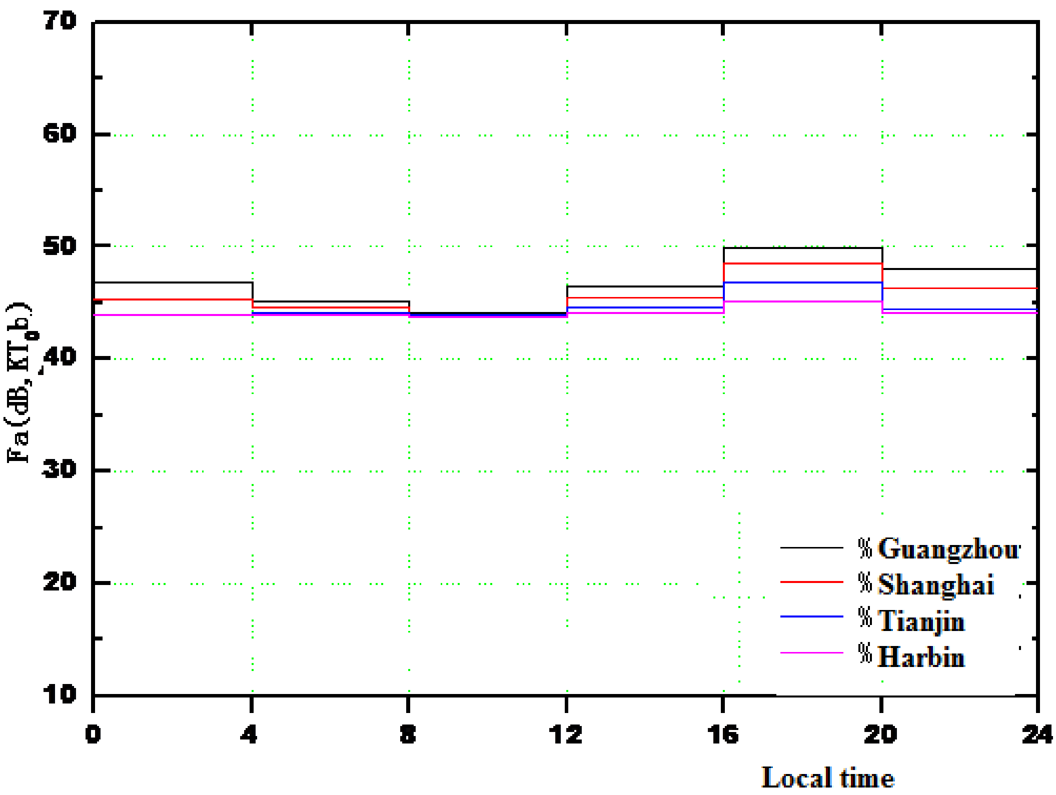

Figure 5.13 Background radio noise intensity (Suburban, 11MHz)

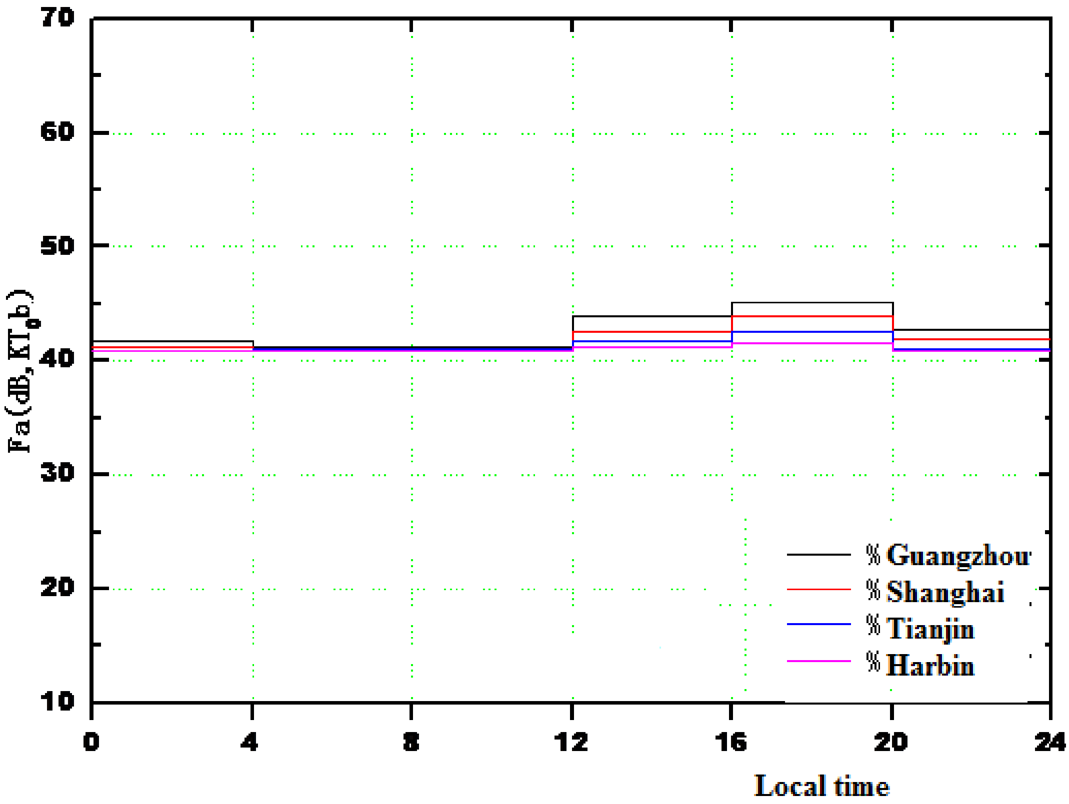

Figure 5.14 Background radio noise intensity (Suburban, 14MHz)

Whether in the rural or suburban level, the noise intensity of the four stations in the 5MHz-14 MHz frequency band are different. That is, the higher the frequency of each station, the lower the noise intensity of the background radio.

The background radio noise intensity at each station is different at any time. In general, the radio station background noise strength is lower in daytime, the time radio background noise intensity is high at night; and the strength of the diurnal variation with the frequency, the lower the frequency, the difference of background noise intensity is greater.

Regardless of the rural or suburban level calculations, the background noise intensity of the four stations varies with geographical location. Under the same environmental noise category, the lower the latitude, the higher the background radio noise intensity. From the results of the four stations, it can be seen that the background noise intensity of the stations in Guangzhou and Shanghai is always higher than that of the stations in the same frequency region of Tianjin and Harbin.

Although radio noise intensity varies with geographical coordinates, this change is not linear. From Guangzhou Station to Harbin Station, two stations between each adjacent latitude difference is about 6-8 degrees, but the change of background noise intensity of adjacent stations is not equate. From the calculation results, the background noise intensity of the two stations in Shanghai and Tianjin is different, while the background radio noise intensity of the two stations in Tianjin and Harbin is smaller.

We could conclude that under the same noise environment, the higher the latitude is, the lower the background noise intensity is. Therefore, from the point of view of the background radio noise, the Harbin Station is the best in the four stations, followed by the Tianjin Station, the second is the Shanghai Station, and the worst is the Guangzhou Station.

Although the radio noise intensity varies with the geographical coordinates, this change is not linear. The calculation results can be seen from four stations in Guangzhou and Shanghai, the background noise intensity of the same frequency is always higher than that of Tianjin and Harbin background radio noise intensity, but under the same environmental noise level, Tianjin and Harbin are almost the same.

Chapter 6

Comparative analysis of ship sailing data

In August, 2015, Yongsheng sailed from the port of Dalian in northeast China to Rotterdam on a test run through what is known as the Arctic Northwest Passage. Table 6.1 shows the communication between the Yongsheng and Tianjin/Guangzhou Radio Station.

Table 6.1The communication between the Yongsheng and Tianjin/Guangzhou Radio Station

	Time	Frequency(kHz)	Quality	Note
August 3	17:04	18795	low	Communicated with Tianjin Radio Station. No response from Guangzhou Radio Station.
	17:08	18795	good	
	18:17	18795	good	
August 12	07:33	18819	none	Communicated with Guangzhou Radio Station. No response from Tianjin Radio Station.
	20:26-20:46	18819	none	
	20:53-21:00	18795	none	
August 13	07:50	18819	none	No signal from both stations

Source: Completed by the author.

Because the specific location of ship cannot be identified exactly, we located the ship in the center of Arctic regions of our study (E101°,N77°). The time is in August 2015, is in the middle of the solar activity, with sunspot number is 71. The distance from Guangzhou Station to the ship is 6002 kilometers, and the distance from Tianjin Station is 4302 kilometers. The following aspects are analyzed from two aspects of available frequency band and SNR.

(1) The available frequency band

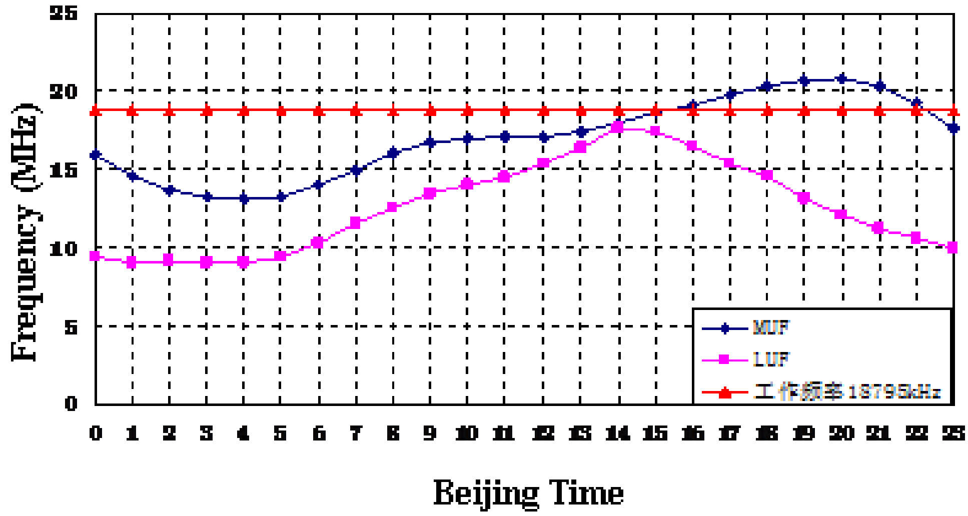

Figure 6.1 Daily variation of MUF/LUF of Guangzhou Station in Aug, 2015

Source: Completed by the author.

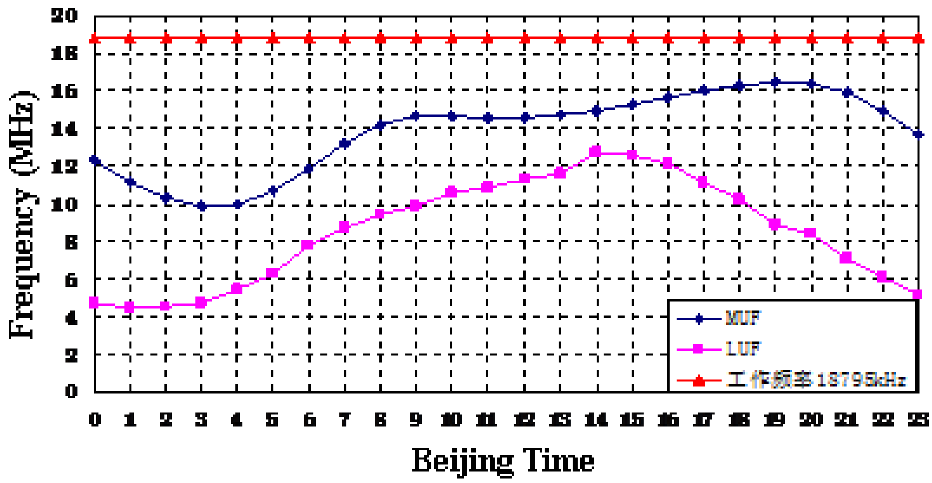

Figure 6.2 Daily variation of MUF/LUF of Tianjin Station in Aug,2015

Source: Completed by the author.

(2)SNR

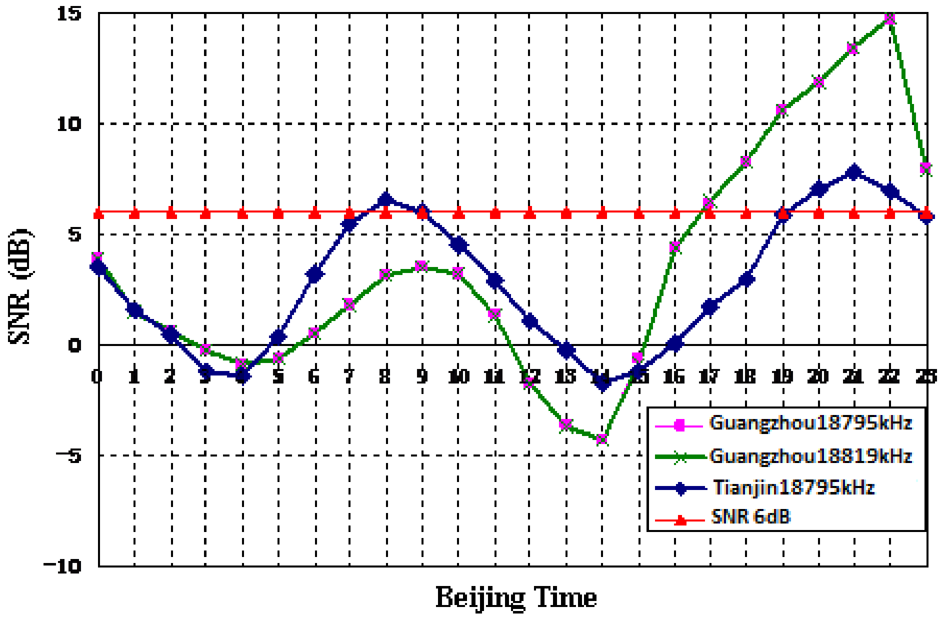

Figure 6.3 Daily variation of SNR of Guangzhou Station and Tianjin Station in Aug, 2015

Source: Completed by the author.

In Figure 6.1 and 6.2, we can see Guangzhou Stationand Tianjin Station received signals during the morning 7:30-8:00 am, 17:00-21:00 pm. From Figure 6.3 the SNR model, it can be seen in the time periods between 7:00-11:00 am and 17:00-23:00 pm is relatively higher SNR period coincided with the actual communication which can receive the signal with time round Yongsheng, indicating that the actual test results and the model are basically in accordance with each other.

But at the same time we can see, on August 3rd 17:04-18:17, the 18795 kHz frequency signal was received from Tianjin Station, but no answer from Guangzhou Station. It can be seen from Figure 6.3, SNR of Guangzhou is greater than Tianjin Station, but Guangzhou has not received signal, there are also some differences with the model prediction results. Thus we conclude that, the actual test results are basically consistent with the model predictions. But the model calculation results reflect the medium and long term statistical rules, which can be used to guide the system demonstration in the early stage, and have a certain reference value for the communication link frequency selection and communication effect evaluation. And it can be seen that multi station protection can improve the rate of communication.

Chapter 7

Conclusion

7.1 Main researches in this paper

The achievements of this paper provide a theoretical guidance for the construction of the communication system in CRS aim to serve for Arctic communication. In order to make full use of the four stations, to build a comprehensive and effective service system, in the subsequent construction of the actual system, we need to consider the following aspects of work:

(1) Build self-adaption frequency management system for Guangzhou, Shanghai, Tianjin and Harbin coastal stations, so that the stations will always work in the best frequency to ensure a higher rate of communication when serving for the ships in the Arctic route.

(2) Establishing the Arctic route short-wave communications guarantee task planning center, through distributing and utilization the ionosphere channel data of Tianjin, Harbin, Guangzhou and Shanghai stations of self-adaption frequency management system to implement granting work period, frequency planning and task, so as to realize the multi-station comprehensive security for Arctic channel communication, which will greatly enhance the rate of communication of Arctic channel.

(3) Test the actual noise measurement for Tianjin, Harbin, Guangzhou, Shanghai and other coastal stations, to provide necessary data support for the design of receiving system, to update the accuracy of data.

(4) Establish a dedicated short-wave communication link between China and Arctic route, to obtain ionospheric channel data, and to carry out domestic and Arctic short-wave communication research, so as to further enhance the design level and performance of short-wave communication system.

7.2 Inadequacies of this paper

SNR is an important parameter to calculate the quality of received signal in this paper, because of lack of the actual data of coast radio station ,in the process of calculation ,just simulation as the basic level.

This paper is based on theoretical calculation, but in practice, the short-wave communication would be affected by several factors, the actual geography, environment, weather, and other factors also influence the ionosphere, especially short

-wave communication. The distance between China and Arctic is very large, there is a big uncertainty, individual bias is very likely in practice, so it is better to be improved in the future along with the rich of actual measurement data.

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