The Design of Public Aerating System

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Abstract. Microwave receiver system is signal receiving equipment in radio astronomical observation. Through refrigeration, we can greatly reduce the noise temperature of receiver, but the dewar has more than 200 K temperature difference between inside and outside, and the vapor will freeze on the surface of vacuum window to effect observation. The aerating system is a pneumatic control system, it supplies dry air and exhausts old for dry air cavity of receiver. Three cryogenic receivers of Nanshan 26 m radio telescope were equipped with aerating systems, but they were independent each other. The public aerating system could not only realize to supply dry air for three cavities, but also had a simpler structure with only one inflator. Compared with the test results of original systems, the public aerating system could make the pressure of each cavity more stable, and keep dry for each vacuum window of cryogenic receivers very well.

Introduction

The microwave receiver is a device which collects the electromagnetic wave signal from the telescope and amplifies the radio frequency(RF) signal through a low noise amplifier(LNA) [1,2], and then outputs it to backend after mixing, intermediate frequency(IF) amplification and filtering[3]. Because the signals received in radio astronomical observation are extremely weak, the sensitivity of receiver is highly demanded for radio telescope[4]. The noise temperature is an important parameter to measure the sensitivity of receiver. The lower the noise temperature, the higher the sensitivity. Because refrigeration can reduce the noise and enhance the sensitivity of microwave devices, it is necessary to provide a low temperature environment for microwave devices of the receiver, so that the temperature of these devices can be reduced to below 20K. A common method is to design a special dewar cavity for refrigeration to install and place these cryogenic microwave devices.

A kind of cryogenic receiver with external feed is shown in Fig. 1(a). This design is generally due to the large feed size of the long cm band receiver, which cannot be cooled as a whole, so the receiver feed is placed outside the dewar. The RF signal first passes through the normal temperature feed to the vacuum window, and then passes through the vacuum window to the low temperature ortho-mode transducer(OMT) [5] and LNA in the dewar. The other kind is shown in Fig. 1(b). This design is due to the small feed size of the short cm or mm band receiver, which is convenient to place the feed and other microwave devices in the dewar as a whole to be cooled together.

Regardless of whether the feed of the receiver is refrigerant, there are three points to consider. First, the vacuum window needs to be sealed to ensure the vacuum in the dewar cavity; secondly, the sealing material needs to hold the pressure of an atmospheric pressure; finally, the sealing material needs to have as little insertion loss as possible to the incident signal [6]. Because the temperature of sealing material is between 80 K and 300 K during the operation of cryogenic receiver, if it is exposed directly in the air, the water vapor in the air will adhere to the surface of cryogenic sealing material and be frozen. This will not only corrode the sealing material, but also increase the insertion loss and standing wave of the receiver, thus affecting the performance of the receiver.
The aerating system is a pneumatic system, it supplies dry air and cleans old air for dry air cavity, so it can avoid the vapor freezing on the surface of vacuum window to effect observation.

**Design Idea of the Public Aerating System**

**Aerating System of C Band Cryogenic Receiver**

The C-band cryogenic receiver of the 26 m radio telescope at Nanshan of observation frequency is 4720-5110 MHz. Because it is a kind of cryogenic receiver with external feed, the aerating system directly designs the feed as a dry air cavity. The top part of feed is sealed with wave-transmitting material, and the bottom is connected with the vacuum window of dewar and sealed. The dry air is continuously supplied into feed by the inflator[7]. The pressure of feed is monitored by monitor unit, which can exhaust the old air, so as to keep dry for the vacuum window.

For air supply, the inflator provides dry air with a certain pressure, which is divided into a single port air buffer and an air supply tee. When the pressure of the inflator reaches a set upper limit and stops working, the air buffer will act as another air source, and together with the inflator will supply the remaining dry air with a certain pressure to the feed cavity. The tee is divided into two ways, one way through an air supply hand valve(ASHV), the other way through a air supply solenoid valve(ASSV) (normal close), and then merged to the feed cavity. Adjust the opening of the ASHV to ensure that the dry air from the air source is transmitted to the feed cavity with a small flow rate; when the pressure of the feed cavity is low, the monitor unit controls the ASSV to open to ensure that the large flow of dry air are transmitted to the feed cavity together until the pressure of the feed cavity is normal, then monitor unit closes the ASSV, continues to use the ASHV to supply air with a small flow. For air exhaust, the feed cavity is divided into two ways to exhaust old air, one way through an air exhaust hand valve(AEHV), the other way through an air exhaust solenoid valve(AESV) (normal close). Adjust the opening of the AEHV to ensure that the old air from the feed cavity is removed out of the feed cavity with a small flow rate; when the air pressure of the feed cavity is high, the monitor unit controls the AESV to open to ensure that the large flow of old air are removed out of the feed cavity together until the air pressure of the feed cavity is normal, then the monitor unit closes the AESV, continues to use the AEHV to remove old air with a small flow. As shown in Figure. 2.
Aerating System of K and Q Band Cryogenic Receiver

The K band cryogenic receiver of observation frequency is 22-24.2 GHz, and Q band is 30-50 GHz. Because these two receivers are kinds of cryogenic receiver with internal feed, the aerating system designs a dry air cavity outside the vacuum window specially. The dry air is continuously supplied into the cavity by the inflator. The pressure of cavity is monitored by the monitor unit, which can exhaust the old air, so as to keep dry for the vacuum window drying purposes. As shown in Figure. 3.

The principle of K and Q band aerating system is similar to that of C band, the main difference is that the air buffer is dual port, because the volume of K and Q band dry air cavity is small, the dual port air buffer can handle with the fluctuation amplitude and period of inflator; on the other hand, it can also cope with the change of air pressure caused by the change of flow rate in the system.

Design of Public Aerating System

The public aerating system is a common pneumatic device. This design can simultaneously satisfy the air supply and exhaust functions of three dry air cavity. Firstly, the system uses only one inflator and a single port air buffer, and then directly supplies dry air to the C band feed cavity. Secondly, the old air from feed cavity after high pressure replacement is divided into two ways as the air supply source of the K and Q band dry air cavities; because C band feed cavity is large, it is used as a large air buffer to supply the K and Q band dry air cavity gently. Finally, the K and Q band dry air cavity receives the exhaust air from the C band feed cavity with relatively high pressure, and the old air with low pressure of K and Q band dry air cavity is removed through AEHV, as shown in Figure. 4.
Realization of Public Aerating System
Pressure Design of Each Cavity

In view of the preset air supply pressure of the inflator is 1000-2000 Pa. The sealing material of C-band cryogenic receiver was simulated by ANSYS software. As shown in Figure. 5, when the pressure of feed cavity is 0 Pa (left), the simulation result of the maximum deformation in the middle of the vacuum window is 5.733 mm; when the pressure is 500 Pa (right), the result is 5.743 mm. The maximum deformation of vacuum window is about 6 mm when the cavity pressure is 500 Pa in actual measurement, which is very close to the simulation value of 5.743 mm. The insertion loss of measured sealing material is maintained at about 0.04 dB within the pressure range of 0-2000 Pa in the feed cavity. So the ideal new pressure of C band feed cavity is finally designed to be 500 Pa.

K and Q band dry air cavities are at the back stage of supply link of the public aerating system, the volume of K and Q band dry air cavities are small, and the vacuum windows are same, so the pressure of dry air cavity needs to be slightly lower than the C band feed cavity. The simulation results are shown in Figure. 6, when the pressure of dry air cavity is 0 Pa (left), the simulation result is 8.938 mm; when the pressure is 200 Pa (right), the simulation result is 8.944 mm. The actual measurement of 9 mm is very close to the simulation. The insertion loss is maintained at about 0.05 dB within the pressure range of 0-2000 Pa in the dry air cavity. So the ideal new pressure of K and Q band dry air cavity is finally designed to be 200 Pa.
Build of Public Aerating System

The public aerating system uses commercial inflator to supply dry air with certain pressure to the single port air buffer and the C band feed cavity. The original monitor unit of the C band aerating system is continued to use to realize the air supply and exhaust function of the feed cavity. Then the AEHV pipeline of the C band aerating system is divided into two channels as the air source of K and Q band dry air cavity. The original monitor unit of the K and Q band aerating system is continued to use to realize the air supply and exhaust function of the dry air cavity, but the original dual port air buffer in the K and Q band aerating system is removed (its function is replaced by the C band feed cavity), and the old air in the three cavities are finally removed outside by the air exhaust hand valve of K and Q band. In order to realize 500 Pa pressure of C band feed cavity and 200 Pa pressure of K and Q band dry air cavity, the opening and closing values of ASSV and AESV in each monitor unit of the public aerating system need to be reset, and the opening of ASHV and AEHV also need to be manually adjusted. As shown in Table 1.

### Table 1. Solenoid valves setting of original independent and public.

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<th>Setting of Original Aerating System</th>
<th>Setting of Public Aerating System</th>
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<tr>
<td></td>
<td>ASSV open</td>
<td>ASSV close</td>
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<tr>
<td>C band pressure [Pa]</td>
<td>150</td>
<td>200</td>
</tr>
<tr>
<td>K band pressure [Pa]</td>
<td>300</td>
<td>500</td>
</tr>
<tr>
<td>Q band pressure [Pa]</td>
<td>300</td>
<td>500</td>
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Measurement of Public Aerating System

After several rounds of debugging, the air supply pressure of the inflator is adjusted to 1200 Pa. Fig. 7 shows the operating state of the public aerating system at a certain measurement time, the pressure of C band cavity is 590 Pa, Q band is 320 Pa and K band is 280 Pa.
A test was carried out from September 2017 to January 2018, and the pressure of C band feed cavity was 420-710 Pa(The previous test was 130-340 Pa), K band dry air cavity was 250-310 Pa (The previous test was 290-810 Pa), and Q band dry air cavity was 260-330 Pa(The previous test was 290-710 Pa). Compared with the previous test results of the original independent aerating system, the pressure range of K and Q band dry air cavity decreases greatly. The C band range increases slightly, but the main reason is that the C band feed cavity acts as a air buffer to adjust the pressure of K and Q band dry air cavity, and the overall operation of the public aerating system is more stable than before.

Summary
The public aerating system designed for the C band, K band and Q band cryogenic receivers of 26-meter radio telescope at Nanshan of XAO can simplify the composition of the original aerating systems and still realize the functions more steadily. The public aerating system can use only one inflator to supply dry air for three receivers’ cavities to realize to keep dry for the vacuum windows. However, the inflator used in the public aerating system has been in working all the time, which will make its internal compressor cushion aging, reduce the working life of the equipment, this situation needs to be paid attention to in daily maintenance, and the whole public aerating system needs further research, testing and optimization.

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