# The characteristics of antenna system in Chinese Spectral Radio Heliograph

***Sha Li*[1],Yi Hua Yan[1], Zhi Jun Chen[1] and Wei Wang[1]***

[1]Key Laboratory of Solar Activity, National Astronomical Observatories, Chinese Academy of Sciences, Beijing, China, lisha1400@bao.ac.cn

## Abstract

The Chinese Spectral Radioheliograph (CSRH) is a telescope observing the Sun in radio wavelength on the ground, it uses Eleven antenna as its feed with ultra wide band and dual polarized characteristics. This feed is composed of several folded dipoles arranging in periodic array. In comparison with original Eleven feed, the perfomance of this feed is largely enhanced through some optimized work. The reflection coefficient of this feed is less than -15dB and the axial ratio is below 1.5dB in 0.4-2GHz. After the feed is installed in the reflector antenna, with the use of different terminals added in front end of the receiver, Y factor method is used to measure the antenna noise temperature. The test results show that the noise temperature of antenna IB1 is less than 120K. The pattern of this Eleven feed is shaped well to the radiation pattern of the reflector antenna. With the use of the simulated radiation patterns of the antenna feed, the measured results of the system temperatures are demonstrated as follows.

## 1. Introduction

In solar radio observations, the relatively calm solar atmosphere can be torn asunder by strong, sudden, incident solar flares, it generate high speed electros that emit intense radiation in radio and X-rays. When solar radio waves arrive at the earth, the properties [1] such as flux density at different frequency points, frequency spectrum, polarization, source brightness distribution at one or more frequencies could be detected by the radio instrument. Due to the transient nature of the solar phenomena, it is desirable to observe and record the parameters simultaneously and continuously. To locate the sources of emission and study of the structures of complex bursts, the angular resolution is necessary especially in the meter wavelength because most solar features develop and change quite rapidly. The solar radio bursts may vary in frequency and intensity on time scales ranging from milliseconds to days, due to these reasons, it is necessary to fully explain the characteristics of the solar magnetism, solar radio burst and solar flares et.al. The radioheliograph which will produce two dimensional image with angular resolution, spectral resolution and time resolution become more and more important.

Though we have analyzed different solar activities through instruments that are using in the world, there are also a lot of features that could not be explained with current theories and data. Now in China, a new radioheliograph at centimeter wavelength and decimeter wavelength is being constructed in Mingantu Observatory.

This instrument consists of two interferometer arrays (CSRH-I and CSRH-II), CSRH-I array is comprised of 40 reflector antennas with 4.5-m dishes from 0.4-2GHz and CSRH-II array is comprised of 60 reflector antennas with 2-m dishes from 2-15GHz. The reflector antenna uses Eleven antenna as its feed. The previous Eleven feed was developed at Chalmers University in 2006. However, the return loss of this original Eleven feed is about -5 dB in 0.15-1.5GHz, which may meet the requirements of observing other astrophysical objects with slowly changing signals but not suitable for observing the Sun. Another previous Eleven feed shows that the measured S11 is less than -8 dB in 200-800MHz. However, it is still not suitable for solar radio observation with fast changing signals. In this paper, the measured S11 of this optimized Eleven feed is less than -15dB in 0.4-2GHz. The performance of this feed is enhanced in CSRH project. Fig.1 shows the antenna array in the left and UV coverage. About UV coverage, there are some advantages in choosing three spiral arms, such as the UV coverage map is a circularly symmetrical coverage, it could give a solar radio image using sub array model, it also has low side lobe.

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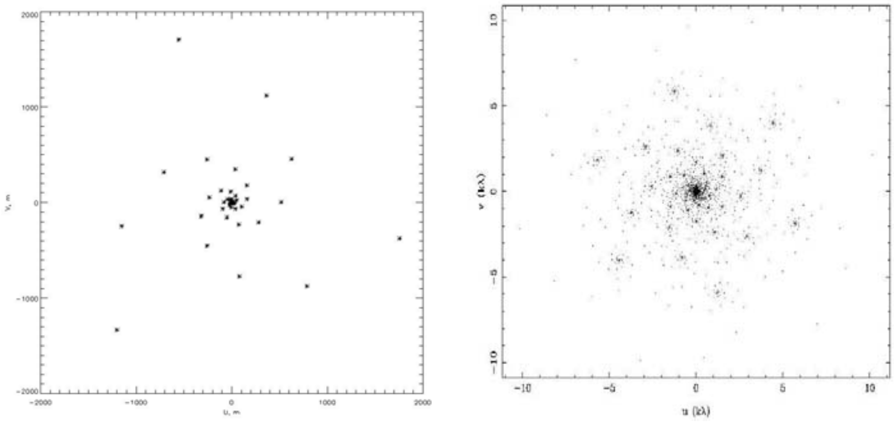

Fig.1. The antenna array of CSRH (left) and UV coverage (right)

## 2. The measured characteristic of antenna system

In solar radio astronomical system, the circular polarization [2] is demonstrated from studies of large numbers of storms. This Eleven feed is composed of several log-periodic folded dipoles and the coaxial lines linked with the microstrip lines. Fig.2 shows the geometry of the Eleven feed . The other side of this feed connected with the circular polarizer 3dB hybrid. Fig.3 shows the measured S parameters.

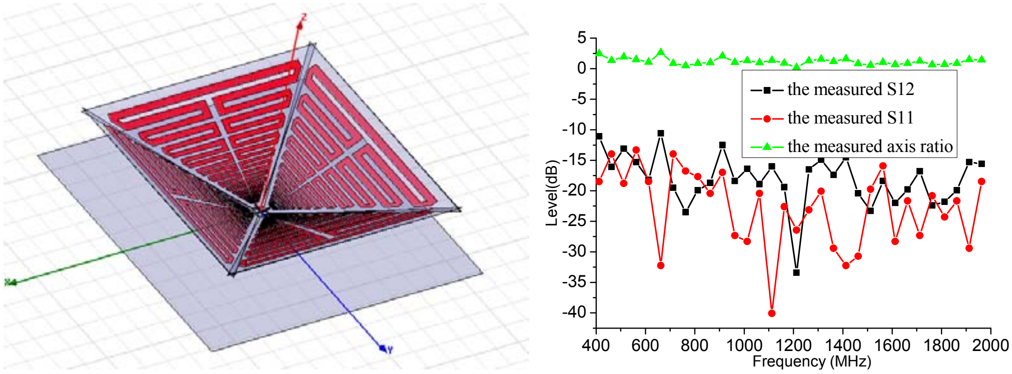


Fig.2 The geometry of the Eleven feed (left) and the measured characteristics(right)

From these results, the measured S12 is less than -10.6dB and S11 is less than -13.23dB, this means that the maximum Voltage Standing Wave Ratio (VSWR) is 1.56, the axial ratio is almost below 1.5dB excluding four frequency points. Fig.3 shows the simulated and measured field radiation patterns in different frequencies, it has equalized patterns. These main characteristics are all satisfied with the requirements of observing the radio sun, it is also better than the previous Eleven feed.

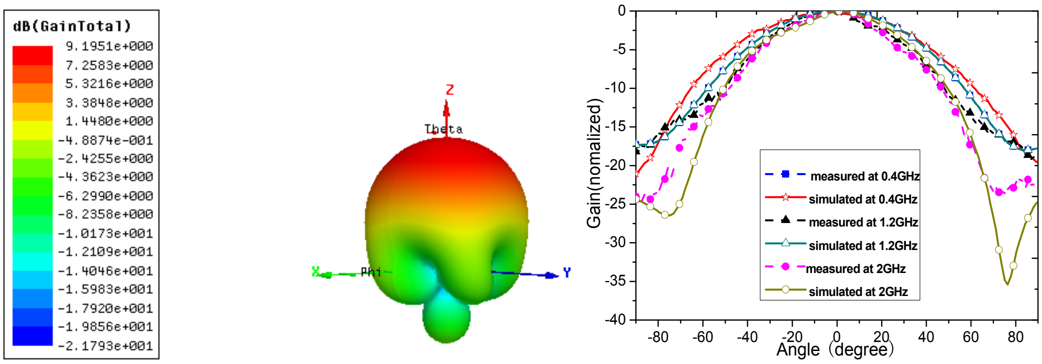


Fig.3 Simulated and measured field radiation patterns

In solar radio map, the correspondence indicates that the storms are polarized in ordinary wave mode, which will be characterized in terms of antenna gain, effective aperture, antenna noise temperature et.al. The reduction of the system noise temperature could improve the sensitivity of a radio telescope. Minimizing the radio noise temperature [3-5] usually involves cooling the amplifier from the front end of the system. In order to convert radio signals into absolute radio image, each antenna system noise temperature should be measured.

It is more reliable and convenient to use the cosmic sources of small angular size for which the flux density is definitely determined. But according to the Sun, it is really not possible to use a cosmic source because the Sun is stronger than any other calibration sources, at the same time, a noise source is added in the analog system of the input port. Comparing its first output with the calibration sources, the receiver port is connected sequentially to the load, the antenna and the standard noise generator. The noise temperature of the receiver and antenna system is measured by Y factor method. The thermal noise sources used in this measurement are impedance resistive load connected to the receiver input by coaxial lines.

$$[(T_{50}+T_{\mathrm{R}})\mathrm{kB}]+[G_{\mathrm{R}}]=[P_{50}]$$
$$[(T_{\mathrm{NS}}+T_{\mathrm{R}})\mathrm{kB}]+[G_{\mathrm{R}}]=[P_{\mathrm{NS}}]$$
$$[(T_{\mathrm{SKY}}+T_{\mathrm{S}})\mathrm{kB}]+[G_{\mathrm{R}}]=[P_{\mathrm{SKY}}]$$

where k=1.3806505*10^(-23) J/K, B represents the frequency bandwidth, $G_R$ is the gain of the system coming from the low noise amplifier to the receiving system. $T_{NS}$ and $T_{50}$ correspond to the terminal of the system [6-8] connecting with the noise source and the standard impedance 50Ω. $P_{50}$ and $P_{NS}$ represents the powers with standard impedance and noise source, $P_{SKY}$ represents powers that the antenna is pointing to the sky. Tr is the system temperature coming from low noise amplifier to the receiving system [9-11].

The IB1 antenna is tested in this measurement. Table.1 shows the noise temperature of the noise source, Table.2 shows the power with different ends, from this table, we could know that when the terminal end is connected with noise source, the power is much higher than other two conditions.

Table.1 The noise temperature of the noise source in different frequencies

| Radio frequency(GHz) | ENR(dB) | Noise temperature(K) |
|---|---|---|
| 0.775 | 21.004 | 36832 |
| 0.85 | 21.0369 | 37110 |
| 0.9 | 20.7244 | 34554 |
| 0.925 | 20.6579 | 34033 |
| 1.275 | 19.89 | 28569 |
| 1.375 | 19.5147 | 26224 |
| 1.5 | 19.2973 | 25021 |
| 1.7 | 18.67 | 21677 |
| 1.975 | 18.36 | 20184 |

Table.2 The power with different ends

| Radio frequency(GHz) | Noise source(dBm) | 50Ω(dBm) | sky (dBm) |
|---|---|---|---|
| 0.775 | -28.93 | -45.87 | -47.38 |
| 0.85 | -23.02 | -41.34 | -43.31 |
| 0.9 | -23.93 | -41.7 | -43.6 |
| 0.925 | -23.69 | -41.6 | -43.38 |
| 1.275 | -28.83 | -45.25 | -46.68 |
| 1.375 | -30.08 | -46.92 | -49.16 |
| 1.5 | -31.08 | -46.51 | -47.99 |
| 1.7 | -28.22 | -44.13 | -45.83 |
| 1.975 | -30.67 | -45.91 | -47.33 |

Table.3 represents the calculated results in different frequencies, the gain of the receiver is about 62dBi. The antenna temperatures are less than 120K in these listed frequencies.

Table.3 The calculated results in different frequencies

| Radio frequency(GHz) | $P_{NS}/P_{50}$ | $P_{sky}/P_{50}$ | Tr (K) | $G_R$(dB) | $T_A$(K) |
|---|---|---|---|---|---|
| 0.775 | 49.43 | 0.71 | 464.5 | 59.18 | 68 |
| 0.85 | 67.92 | 0.64 | 260.2 | 65.08 | 89 |
| 0.9 | 59.84 | 0.65 | 292.3 | 64.48 | 84 |
| 0.925 | 61.8 | 0.66 | 264.9 | 64.79 | 103 |
| 1.275 | 43.85 | 0.72 | 369.9 | 60.38 | 104.8 |
| 1.375 | 48.3 | 0.6 | 258.2 | 59.52 | 69.1 |

| | | | | | |
|---|---|---|---|---|---|
| 1.5 | 52.48 | 0.99 | 190.4 | 59.79 | 80 |
| 1.7 | 38.99 | 0.68 | 272.9 | 62.2 | 107.67 |
| 1.975 | 33.42 | 0.72 | 323.64 | 60.04 | 118.8 |

## 3. Conclusion

This Eleven feed used in CSRH project is manufactured, optimized and measured in the lab. The specification VSWR is less than 1.5 and the axial ratio is less than 1.5dB too. It is good enough in the series of wideband feeds. The method of measuring the antenna noise temperature IB1 is also described in this paper. From these results, we could know that the reflection coefficient of the feed is suitable for CSRH. The gain of the receiver including the optical transmitter and receiver, low noise amplifier and other elements is about 62dBi. Here, a radio telescope antenna could be regarded as a radiometer at which the antenna beam is directed. The method of calculating antenna temperature could be helpful for analysing other radio telescope.


## 4. Acknowledgments

This work was supported in part by National Major Scientific Equipment R&D project under Grant ZDYZ2009-3. The feed measurement was supported by National Natural Science Foundation of China NSFC grants (Nos.: 11221063, 10778605, Y011141001).


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