Review of recent developments of the eleven feed for future decade bandwidth radio telescopes

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Abstract

The Eleven feed is a compact, low-profile decade-bandwidth log-periodic dual-dipole array antenna. It has many advantages: a constant phase center location, constant beam width over a decade bandwidth, high BOR efficiency, low cross polar level and good reflection coefficient, all over a decade bandwidth. This paper reviews the recent developments on the Eleven feed technology, which covers several important issues for the applications of the feed in decade bandwidth radio telescopes.

1 Introduction

Large decade-bandwidth radio telescopes are required in the future radio astronomy due to their many advantages over the narrow band ones: super-sensitivity, simultaneous multi-channel observations, time-response observations, and etc.. The mid-frequency (1-10 GHz) dish array of the SKA (Square Kilometer Array) and VLBI2010 (Very Long Baseline Interferometry 2010) reflector antennas (2-14 GHz) are two examples.

The requirements for feeds for reflectors in these large decade-bandwidth radio telescopes are extremely high: over a large decade band, high BOR efficiency, constant phase center location, constant beam width, low cross-polar level and low reflection coefficient are demanded in order to have high aperture efficiency and high $G/T$ value, and compact size and cryogenicity of the feed are critically concerned for locating the feed in a cryostat to reduce the system noise temperature. Facing this challenge, a new feed technology - the Eleven feed was proposed by P.-S. Kildal [1] and has been developed by the Chalmers team since 2005.

The Eleven antenna is a decade-bandwidth log-periodic dual-dipole array. It has two unique radiation characteristics: constant beamwidth and fixed phase center location over decade bandwidth. In addition, it has low profile and simple geometry. Therefore, the Eleven antenna is a very good candidate for decade bandwidth feed for reflectors for radio telescopes, which has been demonstrated in [2-6].

This paper briefs the recent developments on the Eleven feed technology, which covers several important issues for the applications in decade bandwidth radio telescopes.
2 Cryogenic 2-13 GHz Eleven Feed for VLBI 2010

Fig. 1 shows the 2 - 13 GHz Eleven feed. Fig. 2 shows the simulated and measured reflection coefficient of the 2 - 13 GHz feed, which are below -10 dB over the frequency band. Fig. 3 shows the aperture efficiency and its sub-efficiencies when the feed illuminates a parabolic reflector with subtended angle of $2 \times 60^\circ$. The efficiencies are calculated based on the measured complex far fields. From the figure, it can be observed that the BOR$_1$ efficiency is higher than -1 dB from 2.5 to 10 GHz, higher than -1.5 dB in the range 2-2.5 GHz and 10 - 13 GHz; The polarization efficiency is high ($e_{pol} > -0.2$ dB), as well as the phase efficiency ($e_{\phi} > -0.1$ dB). The high phase efficiency is achieved because the phase center of the Eleven antenna is located almost exactly at the ground plane, over the whole frequency band. The illumination efficiency $e_{ill}$ is about -1 dB at all frequencies. The frequency variations of $e_{ill}$ are small due to the almost constant beamwidth of the radiation pattern over the whole frequency band 2 - 13 GHz.

![Graph of simulated and measured reflection coefficient](image1)

**Figure 2:** Simulated and measured reflection coefficients of the 2-13 GHz Eleven feed.

![Graph of aperture efficiency and sub-efficiencies](image2)

**Figure 3:** Aperture efficiency and its sub-efficiencies based on measured complex far fields.

3 Cryogenic Compact 1.2-10 GHz Eleven Feed for SKA

Fig. 4 shows the model and a photo of a compact 1.2 - 10 GHz Eleven feed with a cylinder emulating the cryostat. The compact design is done by folding down the outermost 3 non-radiating elements for the band of 1.2 - 10 GHz. The function of these outermost 3 non-radiating elements is therefore to create a termination of the log-periodic array in order to have the same radiation performance at the lower end of the band as at the rest frequency points and a good input reflection coefficient over the total operating band. The compact feed has only 40% volume of the standard one. Therefore, the same compact cryostat for 2 - 13 GHz Eleven feed can be used for the 1.2 - 10 GHz feed. The measured and simulated reflection coefficients of the compact Eleven feed are shown in Fig. 5, which are below -10 dB over the most part of the 1.2 - 10 GHz band, and there are only a few peaks above the -10 dB level, and all of them are below -8 dB. Fig. 6 shows the measured co- and cross-polar radiation patterns in $45^\circ$ plane. It can be seen that the beamwidth of the pattern is nearly constant.

![Model and photo of compact 1.2-10 GHz Eleven feed](image3)

**Figure 4:** Model and Photo of the compacted 1.2 - 10 GHz Eleven feed with a cylinder emulating the cryostat.
4 Decade bandwidth Balun feeding Network for Eleven Feed

The feeding network is a critical component in the design of the Eleven antenna, and a challenge especially for high frequency applications. Fig. 7 shows the configuration of the new passive balun feeding solution, and the simulated and measured reflection coefficient of the back-to-back balun test structure is presented in Fig. 8. From it, we can see that the performance of the balun is below -10 dB over the decade bandwidth. More results will be presented in the conference.

5 Noise Modeling

The system noise model has been set up for the system representation in Fig. 9. Fig. 10 shows the predicted and measured system noise temperature for the 2 - 13 GHz Eleven feed, which exhibits that the noise temperature is about 20 - 30 Kevin over a wideband.
6 Conclusion

This paper reviews the recent developments of the Eleven feed for future large decade bandwidth radio telescopes, which exhibits the potential of the Eleven feed technology.

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8 References


