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

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_1 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

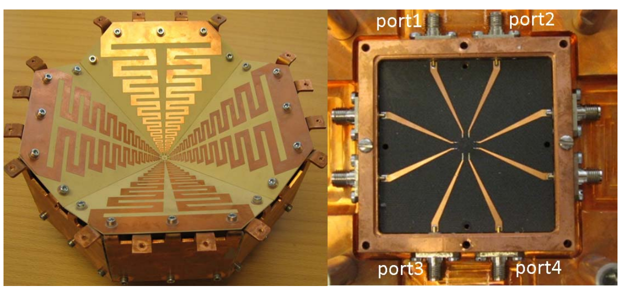

Figure 1: The 2-13 Eleven feed and the descrambling board at the rear side of the ground plane (amplified, not in scale).

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_1 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.

978-1-4244-6051-9/11/$26.00

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 $2 \times 60°$. 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 -1dB from 2.5 to 10 GHz, higher than -1.5 dB in the ranges 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.

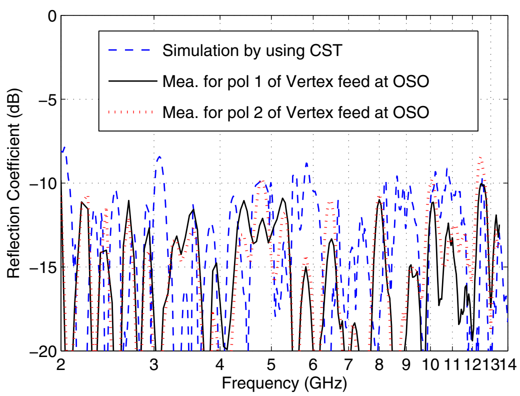

Figure 2: Simulated and measured reflection coefficients of the 2-13 GHz Eleven feed.

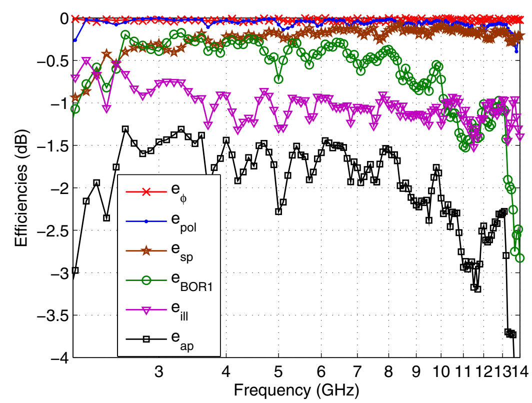

Figure 3: Aperture efficiency and its subefficiencies based on measured complex far fields.

3 Cryogenic Compact 1.2-10 GHz Eleven Feed for SKA

Figure 4: Model and Photo of the compacted 1.2 - 10 GHz Eleven feed with a cylinder emulating the cryostat.

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° plane. It can be seen that the beamwidth of the pattern is nearly constant.

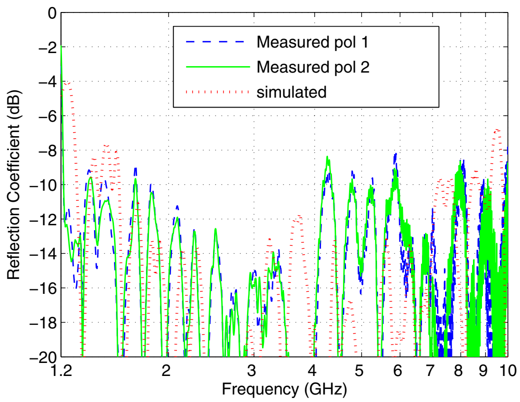

Figure 5: Simulated and measured reflection coefficients of the 1.2-10 GHz Eleven feed.

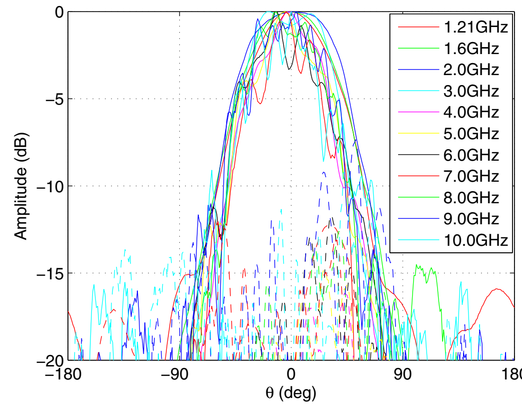

Figure 6: Measured co- and cross-polar radiation patterns in 45° plane of the 1.2 - 10 GHz Eleven feed.

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 specially 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.

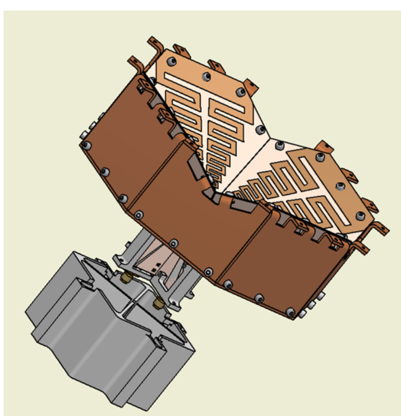

Figure 7: Arrangement of four baluns behind the ground plane for dual polarized Eleven feed.

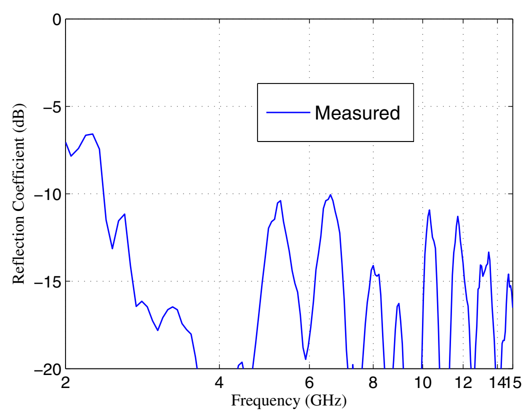

Figure 8: Measured reflection coefficient of back-to-back balun test structure.

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.

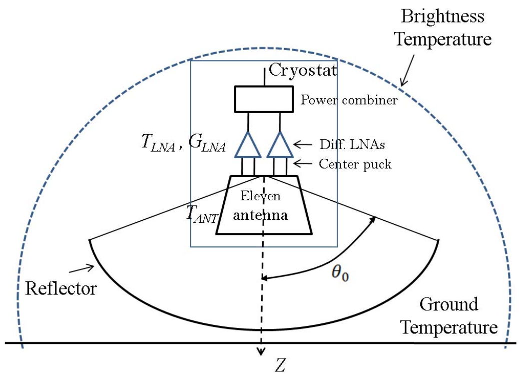

Figure 9: Illustrations of noise models and test scenarios.

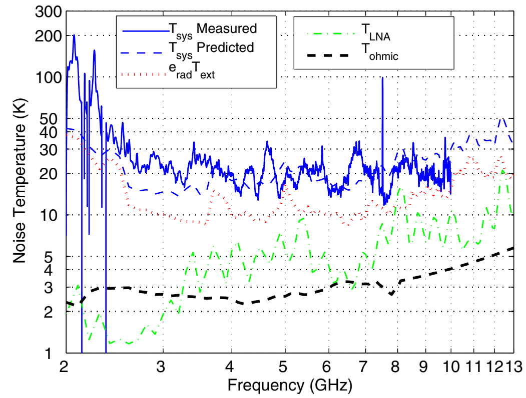

Figure 10: Measured (by Haystack Observatory) and predicted T_{sys} when the feed points vertically towards the sky.

6 Conclusion

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

7 Acknowledgments

This work has been supported partly by The Swedish Foundation for Strategic Research (SSF) within the Strategic Research Center CHARMANT. The authors would like to thank Christopher Beaudoin for his measurements at MIT Haystack Observatory shown in Fig. 10.

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