A Wideband Dipole Feed for Big Reflector Antenna

Yu Jinglong Jin Chengjin
National Astronomical Observatories, Chinese Academy of Sciences
Datun Rd. A20, Chaoyang District, Beijing, China, 100012

***Abstract*-A wideband dipole feed with symmetrical E&H plane patterns is presented for use in reflector antennas. In this paper we describe the design, construction and characterization of a wideband dipole feed for FAST antennas covering the frequency range 70 to 140 MHz. Main goals of our design are, 1) covering octave bandwidth, 2) the feed has symmetrical E & H plane patterns, and 3) the physical dimension is suitable for mounting it in the reserved position of the FAST feed cabin . We hope that four frequency range of FAST antennas will be equipped with this wideband dipole feeds. Preliminary simulation results indicate that we have met most of our design goals.**

I. Introduction

The Five hundred-meter Aperture Spherical Radio Telescope (FAST) is a national facility available for carrying out astronomical and astrophysical studies. It is the largest single-aperture radio telescope in the world with aperture of 500m diameter. Multi-beam and multi-band receivers will be installed covering a frequency range of 70MHz - 3 GHz. The feed system for octave bandwidth below about 1 GHz is currently not available.

It is well known that the most common feeds of the reflector antenna are resonant half wave dipoles and small open-ended waveguides or horn antennas. The half wave dipole can get nearly symmetrical E- and H-planes radiation pattern by using two parallel dipoles with half wavelength spacing [1], or by locating a metal ring of about one wavelength diameter above the dipole [2], [3]. However, it is very difficult to realize octave bandwidth because of limitation of different dipole structure. The feed described in the present paper is kind of two parallel dipole feed using new structure with octave bandwidth.

The horn feeds became very popular during the eighties. In particular, corrugated horns are popular as feeds for dual reflector antennas, and they can have octave bandwidth [4], [5]. The feed used in primary-fed reflectors is often a choke horn. This kind of feed can achieve small variation of the beam-width and the phase center location over a bandwidth of 1.8:1 [6]. But the above mentioned two kinds of horns will be made very large if they used in low frequency bandwidth such as below about 1 GHz.

The main objective of the present work is to research and develop an octave bandwidth feed for the big reflector antennas such as FAST below 1 GHz and to use the feed system to scale in other low frequency range.

II. Characterization of Feed

The main goals of the feed system design were to obtain a reasonable aperture efficiency, symmetrical E & H-plane patterns and, a suitable physical dimension for mounting it in the reserved position of the FAST feed cabin. For low frequency, two kinds of feed system have been used in radio telescope. One is the Fat Dipole of ASTRON with 1.56:1 bandwidth [7]. The other one is V-folded Dipole of GMRT with VSWR < 2 over the frequency range 55 to 80 MHz [8], [9]. It is difficult for both of the above mentioned feed to cover octave bandwidth with VSWR < 2. So the desired frequency range of operation (70-140 MHz) for FAST should be researched and kept development.

The design parameters that one can achieve a good performance of the feed are:

a) The distance between the two parallel dipoles is half wavelength spacing.

b) The shape of the dipoles to achieve the required bandwidth.

c) The two parallel dipoles with ground plane.

Some conventional wideband dipole antenna include: the planar wideband dipole (blade, bowtie, diamond, elliptical, etc.), the sleeve volumetric dipole, the droopy-blade dipole and the folded dipole of different variations etc. A modified fat dipole antenna used in ground penetrating radar (GPR) system with a broad bandwidth, between 100MHz and 350MHz is developed by Korea Electro technology Research Institute [10].

A new volumetric ribcage dipole configuration used in wideband UHF for Digital TV system is researched by F. Scappuzzo [11]. In this paper, HFSS is used to model ribcage dipole antenna design with some improvements for this kind of dipole.

a) The coaxial line is used for feed line instead of original design.

b) The shape of the dipoles is modified to achieve the required bandwidth.

III. Feed Design

The ribcage dipole is similar to the droopy-blade dipole because it occupies the volume beneath the antenna and provides a capacitive coupling to the ground plane; however, it is different because it forms a well-confined metal cavity.

On the other hand, when the sleeves or ribs are missing, the ribcage dipole is reduced to the planar wide-blade dipole.

The ribcage structure with rectangular metal-sheet wings enables a low-cost design. Use HFSS as simulation environment for feed design. At the same time, the coaxial line is used for feed line instead of original design. The geometry for the ribcage dipole, including feed line is shown in Figure 1.

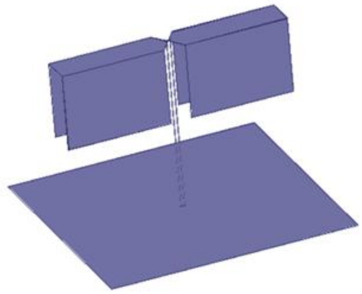

Figure 1. Ribcage dipole above finite ground plane.

Figure 2 presents the simulated return loss for Figure 1 model.

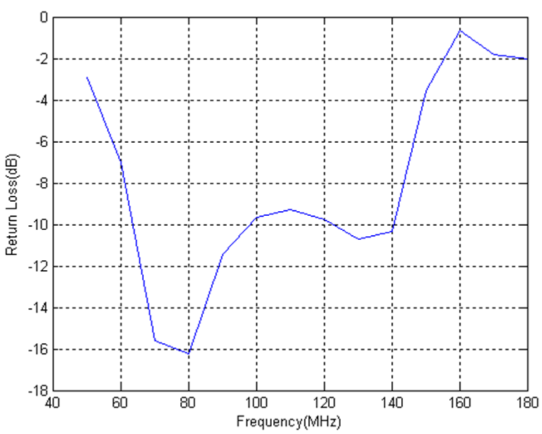

Figure 2. the simulation return loss for ribcage dipole

In this study we focus on the octave bandwidth from 70MHZ to 140MHz. Clearly, the ribcage demonstrates a broadband behavior with good performance.

All simulations are performed in HFSS13, with the PML boundary, with final meshes of about 22,378 tetrahedral, and with a good convergence history. For parametric optimization, the fast frequency sweep is used; all final results have been controlled using discrete frequency sweep.

IV. IMPROVEMENT OF SHAPE

The shape of the dipoles is the key factor to achieve good performance with wide bandwidth. It is the crux of the matter for the impedance match. So the improvement to the shape of the dipole is necessary.

Figure 3 presents the shape change of the ribcage dipole. The figure is the top view for this dipole. The line changes to curve line from feed point to edge of the dipole. Simulation setup is the same as the above mentioned in section 3.

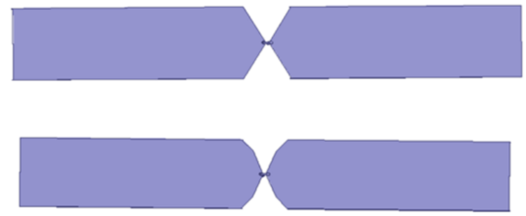

Figure 3. the shape change of the ribcage dipole

The simulation results are shown in figure 4.

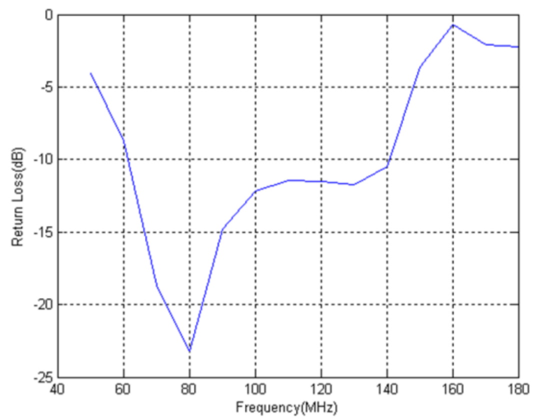

Figure 4. the simulation return loss for shape change of ribcage dipole

We are interested in the feed system consisting of two parallel ribcage dipoles array since it provides symmetric E & H-plane patterns. The configuration of two parallel ribcage dipoles array is shown in figure 5 and the simulation results of radiation pattern is shown in figure 6. The distance between the two parallel dipoles is half wavelength spacing using Figure 1 model.

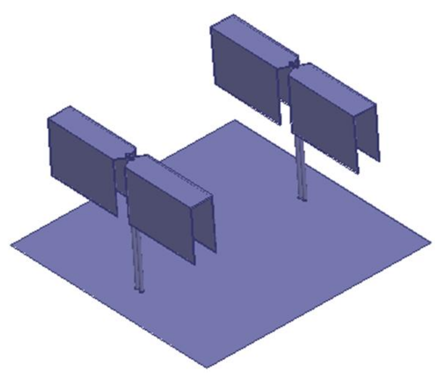

Figure 5. the simulation model for two parallel ribcage dipole array

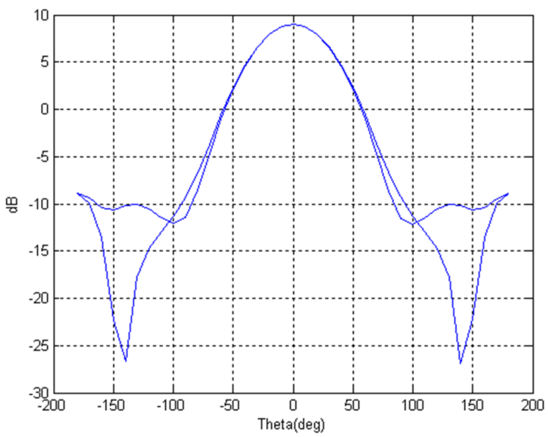

Figure 6. the radiation pattern for two parallel ribcage dipole array

V. CONCLUSION

The present paper has introduced and discussed the use of the wideband ribcage dipole as a single radiator and in a small array environment with symmetrical E & H plane radiation pattern. The simulation results illustrate that the ribcage with shape change is an octave bandwidth feed with VSWR < 2. This kind of feed is a candidate of radiation element for octave bandwidth feed system.

REFERENCES

[1] S. Christiansen and Högbom, Radiotelescopes. Cambridge, U.K.: Cambridge Univ. Press, 1969.

[2] P.-S. Kildal and S. A. Skyttemyr, "Dipole-disk antenna withbeam-forming ring," IEEE Trans. Antennas Propag., pp. 529–534,Jul. 1982.

[3] P.-S. Kildal, S. A. Skyttemyr, and A. A. Kishk, "G/T maximization of a paraboidal reflector fed by a dipole-disk antenna with ring by using the multple-reflection approach and the moment method," IEEE Trans. Antennas Propag., vol. 45, no. 7, pp. 1130–1139, Jul. 1997.

[4] B. Thomas, G. James, and K. Greene, "Design of wide-band corrugated conical horns for Cassegrain antennas," IEEE Trans. Antennas Propag., vol. 34, no. 6, pp. 750–757, Jun. 1986.

[5] B. M. Thomas, K. J. Greene, and G. L. James, "A wide-band primefocus horn for low-noise receiver applications," IEEE Trans. Antennas Propag., vol. 38, no. 11, pp. 1898–1900, Nov. 1990.

[6] Z. Ying, A. A. Kishk, and P.-S. Kildal, "Broadband compact horn feed for prime-focus reflectors," Electron. Lett., vol. 31, no. 14, pp. 1114–1115, Jul. 1995.

[7] E.E.M. Woestenburg, "LFFE Design Review Report", 27 February 2004.

[8] N. Udaya Shankar, K.S. Dwarakanath and Shahram Amiri,et al." A 50 MHz System for GMRT",The Low-Frequency Radio Universe ASP Conference Series, Vol. LFRU, 2009

[9] Shahram Amiri, "A Low Frequency Feed for Big Reflector Antenna", 10th European VLBI Network Symposium and EVN Users Meeting: VLBI and the new generation of radio arrays Manchester, UK September 20-24, 2010

[10] Korea Electrotechnology Research Institute (KERI) & Microline Co., Ltd., "Buried Small Object Detected by UWB GPR", Proc. of Asia Pacific Microwave Conference 2003 (APMC'03), 2003

[11] Scappuzzo, F. S. ; Harty, D. D. ; Janice, B. ; Steyskal, H. ; Makarov, S. N, " A Wideband Dipole Array for Directed Energy Applications and Digital TV Reception", 33rd Annual Antenna Applications Symposium September 22-24, 2009