Publication Year	2017
Acceptance in OA@INAF	2021-01-26T16:31:18Z
Title	Electromagnetic modelling of the 32-m Ghana radio telescope
Authors	Venter, Mariet; BOLLI, Pietro
DOI	10.23919/RADIO.2017.8242212
Handle	http://hdl.handle.net/20.500.12386/30019

Electromagnetic Modelling of the 32-m Ghana Radio Telescope

Mariet Venter
SKA South Africa
Cape Town, South Africa
Email: mventer@ska.ac.za

Pietro Bolli
INAF - Arcetri Astrophysical Observatory
Florence, Italy
Email: pbolli@arcetri.inaf.it

***Abstract*—This paper presents the electromagnetic modelling and supporting results of the African VLBI Network (AVN) Ghana radio telescope at the operating frequencies of 5 and 6.7 GHz. Working from limited technical data, we establish suitable geometrical parameters for the Cassegrain system including modelling and rotation of the four mirrors within the slanted beam-waveguide (BWG). The geometry implemented in GRASP produces several performance values including the effects of the BWG, struts and mechanical tolerances. It is shown that the theoretical maximum gain and aperture efficiency for the antenna at 5 GHz are 63.09 dBi and 72.56%, respectively. The corresponding values at 6.7 GHz are 65.80 dBi and 75.42%, respectively.**

I. Introduction

The African Very Long Baseline Interferometry (VLBI) Network (AVN) is a Square Kilometre Array South Africa (SKA-SA) initiative, funded by the African Renaissance Fund (ARF) and led by the SKA-SA AVN team. This project aims to bring new science opportunities to participating countries and enable participation in SKA pathfinder development by among others, converting several large antennas into radio astronomy telescopes. The first of these, a 32-m telecommunications dish in Kutunse, Ghana (previously owned by Vodafone Ghana) constructed in 1980, is currently undergoing science commissioning to realise VLBI and single-dish capability at 5 and 6.7 GHz, respectively. The AVN team inherited minimal technical documents on the original C-Band performance of the antenna and this paper describes the first attempts to characterise its electromagnetic performance by using powerful modern electromagnetic software packages.

II. Geometry Implementation in GRASP

The Ghana antenna consists of a Cassegrain dual-reflector system with four mirrors in a beam-waveguide (BWG). The GRASP XZ and YZ projections of the antenna geometry with visual ray tracing is shown in Fig. 1. GRASP [1] is a software package developed by TICRA, which provides a set of tools for analysing reflector antennas and delivering their electromagnetic radiation performance. The Cassegrain focus can be seen above the vertex of the primary reflector with the horn focus at the base of the BWG. New supporting struts fitted in 2016, has a circular cross-section with an outer diameter of 425 mm and are placed approximately one third away from the rim of the main reflector.

Table I shows the geometrical data of all reflectors including their (x, y, z) positions relative to the vertex of the primary reflector. The f/d is 0.32 for the primary reflector and the equivalent focal length for the Cassegrain system is 104.69 m. The sub-reflector diameter is 2.896 m.

TABLE I
Geometrical Data of All Mirrors

Mirror	Geometry	Position (m)
Primary	Parabolic, 10.31 m focal length	(0,0,0)
Secondary	Hyperbolic, 9.42 m foci length	(0,0,10.31)
A	Flat, elliptical rim	(0,0,-4.27)
B	Parabolic, 3.71 m focal length	(2.31,0,-4.27)
C	Flat, elliptical rim	(2.31,-1.83,-12.48)
D	Parabolic, 3.71 m focal length	(0,-1.83,-12.48)

According to the labels in Fig. 1, Mirrors A and C are flat, while Mirrors B and D are concave. The flat mirrors are analytically defined by two overlapping ellipses with equal minor axes and unequal major axes. The concave mirrors are cylindrical cut-outs from a paraboloid. The major axis sizes of the four mirrors are between 3.12 m and 3.15 m and the minor axis between 2.21 m and 2.32 m. Mirror C is rotated 45° about the Y-axis and 12.68° about the X-axis resulting in a combined rotation matrix based on optical reflection theory. Mirror B has a simpler rotation only around the X-axis centred on the focal point of the parabola.

The known profiles of the BWG mirrors were used to establish the position of the image created at the Cassegrain focus (directly related to the approximately 7.42 m distance from the focus of parabolic Mirror B to the mirror itself). Using this knowledge together with the information on the primary reflector, a suitable, previously unknown, sub-reflector hyperbolic equation could be established with a foci length and half-subtended angle of approximately 9.42 m and 8.74°, respectively.

III. Results

This section introduces preliminary results as obtained by solving the electromagnetic problem with the Physical Op-

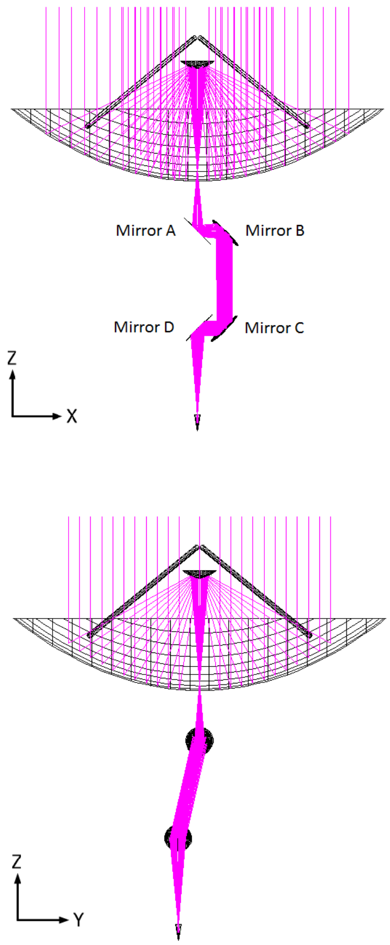

Fig. 1. XZ projection (top) and YZ projection (bottom) of the Ghana antenna geometry in GRASP.

tics method. The system is excited with a Gaussian feedhorn with a -20 dB taper, as specified in antenna documentation [2], where the large taper minimizes the spillover in the BWG. The BWG also has the effect of rotating the far field by 25.3° in azimuth (twice the degree of the slant rotation) and less prominent nulls near the mainbeam. Fig. 2 shows the 6.7 GHz co-polar radiation patterns for the E-plane and H-plane, with various performance values listed in Table II. The cross-polarisation, sidelobe level (SLL) and beam near horizon values are given relative to the maximum gain at zenith. The major impact of the BWG is in the cross-polarisation level. When exciting the system from the Cassegrain focus i.e. without the BWG, the cross-polarisation is approximately -61 dB relative to the maximum gain meaning the BWG has a degrading effect of 23 dB. The struts further degrade the cross-polarisation level with an extra 5.6 dB increase.

Having a reference for the mechanical tolerances is important for the Ghana telescope as it was designed and optimised for a single elevation when observing a geostationary satellite. Apart from the sub-reflector in the primary

TABLE II
GHANA ANTENNA PERFORMANCE VALUES

Parameter	**5 GHz**	**6.7 GHz**
Maximum Gain	63.09 dBi	65.80 dBi
Maximum Cross-polarisation	-36.98 dB	-37.92 dB
Half-power Beamwidth (HPBW)	0.13°	0.096°
SLL	-22.63 dB	-22.90 dB
Beam Near Horizon	-59.11 dB	-53.52 dB
Spillover	0.55 dB	0.45 dB
Aperture Efficiency	72.56%	75.42%

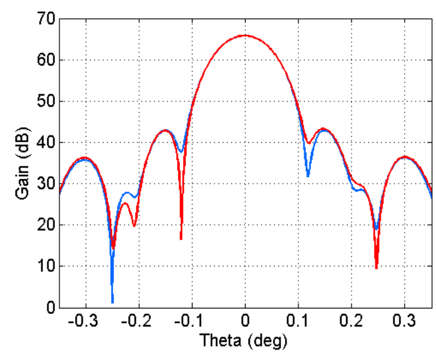

Fig. 2. E-plane (blue) and H-plane (red) radiation patterns of the Ghana antenna at 6.7 GHz.

focus position with its stringent tolerances, lateral offsets and tilting of Mirror A and D have the largest degrading effect on the mainbeam - near 5% of gain for 1° tilt and 0.8% of gain for 4 lateral shifts measured in HPBWs.

IV. Conclusion

Future work includes incorporating an approximation of the current C-Band feedhorn into the GRASP model to replace the Gaussian excitation. Furthermore, as very little is known about the real aperture efficiency of the antenna, physical measurement of the primary and sub-reflector are planned to determine their roughness.

Acknowledgment

The authors would like to thank the National Research Foundation (NRF) and the Department of Science and Technology (DST) of South Africa.

With the support of Italy's Ministry of Foreign Affairs and International Cooperation, Directorate General for the Country Promotion (Bilateral Grant Agreement ZA14GR02 - Mapping the Universe on the Pathway to SKA).

References

[1] *General Reflector Antenna Software Package (GRASP)*, TICRA, Copenhagen, Denmark, [online] Available: www.ticra.com.

[2] *Feed Network FR 6/4-800-01 and -02 and Corrugated Horn CH-65C4*, Spar Aerospace Limited, Quebec, Canada.