An Analysis of Near Fields of 34m Antennas of JPL/NASA Deep Space Network

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***Abstract*— This paper addresses the issue of calculating near fields of the 34m Beam Waveguide (BWG) antennas of the NASA/JPL Deep Space Network (DSN). Calculating the near fields of DSN antennas are of interest in receive mode where the transmitting signals from nearby flying objects such as helicopters and airplanes could interfere with the operation of sensitive RF receiving system of DSN antennas, and in the transmit mode where fields from high-powered DSN antennas interfere with receivers on nearby flying objects, as well as safety considerations for the operators and visitors to the grounds surrounding the antenna sites. A complete and detailed analysis has been performed using PO/PTD techniques, including surface errors and support struts effects. Some results are presented, including comparisons with preliminary field tests.**

Keywords-reflector antennas, near fields; struts; safety concerns; RF interference;

I. Introduction

The high power radiation from the 34 m BWG antennas of JPL/NASA Deep Space Network (DSN) is of some concern when considering the installation of new even more powerful transmitters. These more powerful transmitters are planned to provide up to 80 kW radiating from the feedhorn. The concern particularly includes the radiation effects in the near field, namely around and at the vicinity of antennas at a distances of a few meters to hudreds of meters which might affect the workers and operators, as well as visitors. The concern might even extend to distances of up to perhaps several kilometers which might affect the operation of spacecraft (helicopeters, airplanes, etc.) flying above or near the antenna sites. Thus, by studying the transmitted electromagnetic (EM) fields of the antennas and obtaining the hot spots (i.e., where the field strength is above an acceptable threshould level) in the field, mitigation measures (raising fences, setting proscribed areas, etc.) can be taken, if necessary. Obtaining an accurate evaluation of the near fields, however, can be very difficult and time consuming. This has not been previously done in any detailed and accurate fashion, since most of the attention in the antenna design and analysis has been put into calculating the far-field gain patterns, and even then mostly on the main beam and the first few sidelobes. The main aims of the original design and analysis of these shaped dual reflector systems were primary maximizing peak gain and minimizing the noise entering the highly sensitive receivers[1]. Recently, however, some effort has been put into a first order and approximate calculation of the near fields [2].

The primary concern here is related to the planned construction of two new BWG antennas at the Canberra Deep Space Communications Complex (CDSCC), one of which is slated to be outfitted with new high power transmitter. Accordingly, JPL has funded a multi-year task for accurate evaluation of the EM fields of all antennas at CDSCC and subsequently those at all the other DSN facilities. The analysis task for the new antenns, therefore, fits right into this overall task and is the focus of this particular work.

Theoretical study of the fields have been recently made more feasible by the advent of supercomputers and accurate and well-tested analysis software such as GRASP by TICRA [3]. Of course, some spot measurements must be performed after the analysis, in order to validate and ascertain the theoretcial results to some reasonable degree.

Again, it should be emphasized the t***he human safety issue is the main thrust of this particular study.*** The aim is to make sure that the power density levels are below certain standard levels for operations personnel as well as the public [4].

Accordingly, we have made a fairly accurate model of the antennas including various blockages from struts, subreflector, etc., and performed a complete analysis using primarily the GRASP software from TICRA on JPL supercomputers.

II. DSN Antena System

The DSN antenna system that has been analyzed is a Cassegrain system composed of two reflectors with surfaces that are rotationally symmetric and whose shapes were optimized to avoid blockage of the subreflector, maximize peak gain and minimize received noise [1]. Figure 1 shows a 3D view of the antenna system. The analysis is performed at X band.

The antenna system includes four pairs of support struts for the subreflector as shown in Figure 1. The struts are grouped in pairs of two and are placed on the ϕ=45º cuts at a radius of 321.4612 in. The length of the struts is 458.5172 in and their cross section is shown in Fig.2.

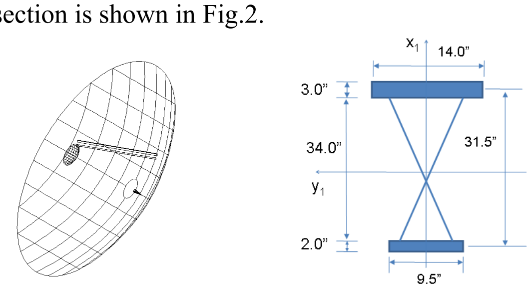

Fig. 1 (a) 3D View of the 34m Antenna System including a pair of struts (b) Strut-pair cross section geometry

III. Struts Analysis

The mechanisms that have been considered in the analysis by which the strut scattering influences the antenna radiation are described in the following:

• *Direct Contribution:* The struts are illuminated by the sub-reflector field and then the impact of the system field is computed (see Fig. 2 a).

• *Plane Wave Contribution:* in this case the struts are illuminated by the reflected field from the main reflector before computing their field contribution (Fig. 2 b).

• *Spherical Wave Contribution:* the third contribution considers the shadowing and changes of the main reflector currents caused by direct subreflector illumination of the struts (Fig. 2 c).

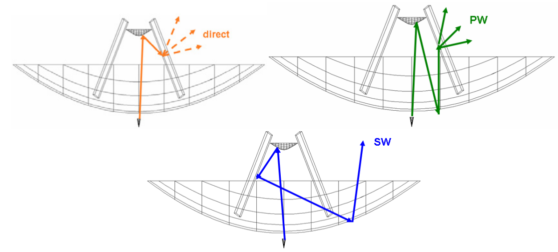

Fig.2 Strut field contributions: (a) Direct, (b) plane wave and (c) spherical wave.

The scattering model used for polygonal struts in GRASP is based on PO and PTD. When the cross section dimensions of the polygonal strut are large in terms of wavelengths, the standard PO method can be used to estimate the scattering from the strut. However, when the dimensions of the strut are decreased, the diffraction by the edges of the strut must be better modeled in order to obtain a satisfactory result. This is accomplished using PTD. The PO/PTD analysis of polygonal struts has been validated with the method of moment (MoM), also implemented in GRASP, at a lower frequency.

IV. Near Field Analysis

As mentioned in the introduction, the primary purpose of this work is to analyze the impact on the near field of DSN antennas by the struts in order to identify possible high field level regions. The analysis has been done with GRASP as explained in the previous section. The near field has been calculated in 3 different grids (see Fig.3 for clarification).

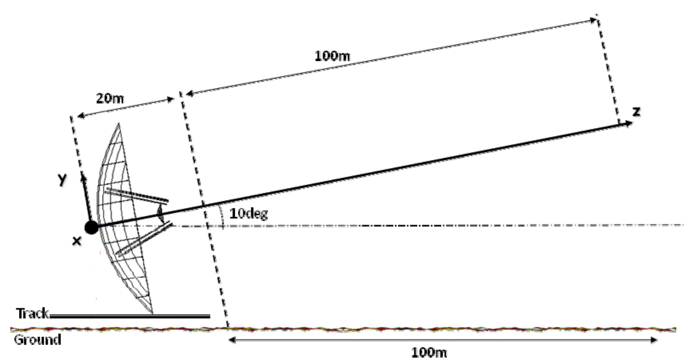

Fig.3 DSN antenna location at 10deg inclination.

Figure 4 shows the near field at a grid for ϕ = [0º to 90º] and ρ = [0 to 90] m at z=120m. The near field was normalized with the maximum field level (-50 dB). One can clearly see the impact of the struts in the region around 45º. The near field analysis was also made at ϕ = 45º cut, where there is the most significant impact of the struts. Figure 5 shows such grid calculated for z = [20 to 120] m and ρ = [0 to 60] m. The impact of the struts on the near field is very significant. Therefore an analysis of the footprint created on the ground was studied and is shown in Fig. 6.

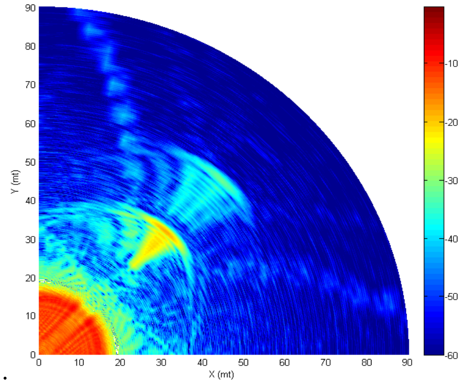

Fig.4 Near field at a grid for ϕ = [0º to 90º] and ρ = [0 to 90] m at z=120m.

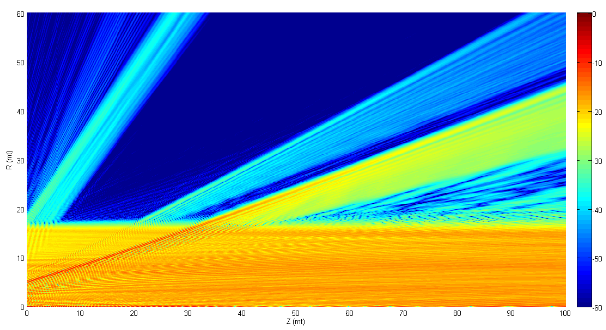

Fig.5 Near field at a grid for z = [20 to 120] m and ρ = [0 to 60] m at ϕ=45º.

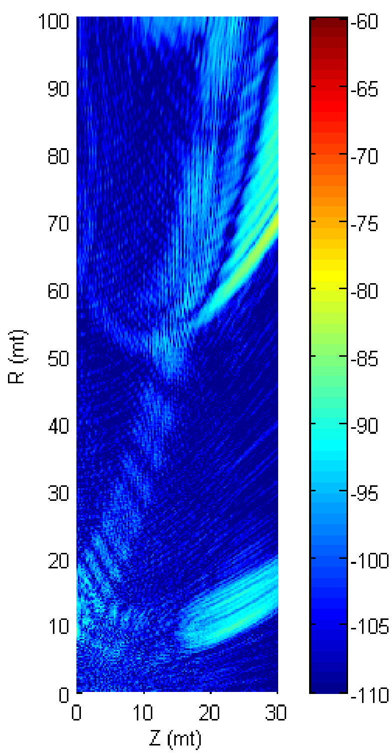

Fig. 6. Near field on the ground for a 10deg inclination of the DSN antenna.

The computation and validations took thousands of supercpomuter hours at JPL, in addition to the processing on the PC's

V. Near Field Measuraments

Some field tests were undertaken to partially corroborate and verify the theoretical results. The experimental verifications can mitigate some of the computational uncertainties and provide some measure of accuracy for theoretical approximations that have been made. However, it should also be noted that the measurements, themselves, are subject to approximations and uncertainties inherent in the nature of measurement devices and their utilization methods and procedures. Nonetheless, spot measurements can provide for some degree of validation and some confirmation for the results.

Power density measurements were performed using a hand-held power-meter by walking around the antenna site with the aid of a GPS survey meter. Narda NBM 550 with 170 nw/cm2 resolution with GPS was used for primary measurements. Measurements were made at two sites, at CDSCC in Canberra, Australia and at GDSCC in Goldstone, California. Detailed results will be the subject of a future report. Here, however, we present a simple non-overplayed graphical comparison in Figures 7(a,b). The fields are calculated and measured at a height of 1.5m from the ground.

The figures show the power densities on the ground level for an antenna elevation of about 10 degrees. The measured results are on uneven terrain with tall wet grass, while the theoretical results assume a perfectly flat terrain. Similarities in the patterns are quite obvious and rather striking. More measurements and better pattern matches have to be performed to further validate the comparisons.

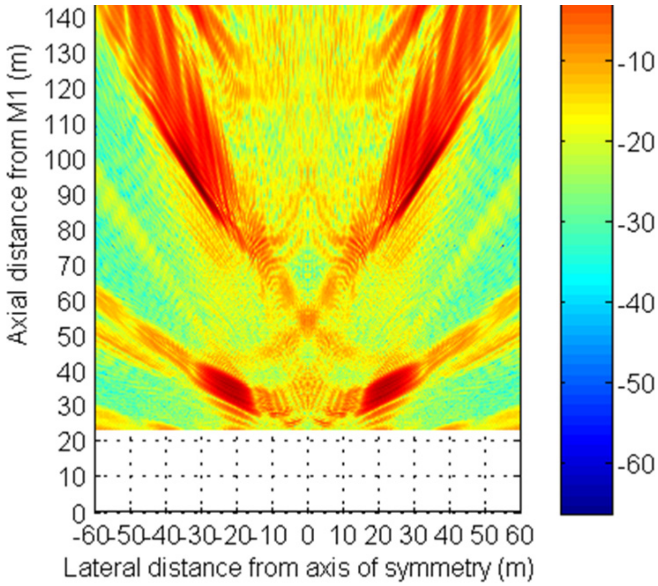

Fig.7(a).Theoretical patterns on the ground in front of the 34m antenna.

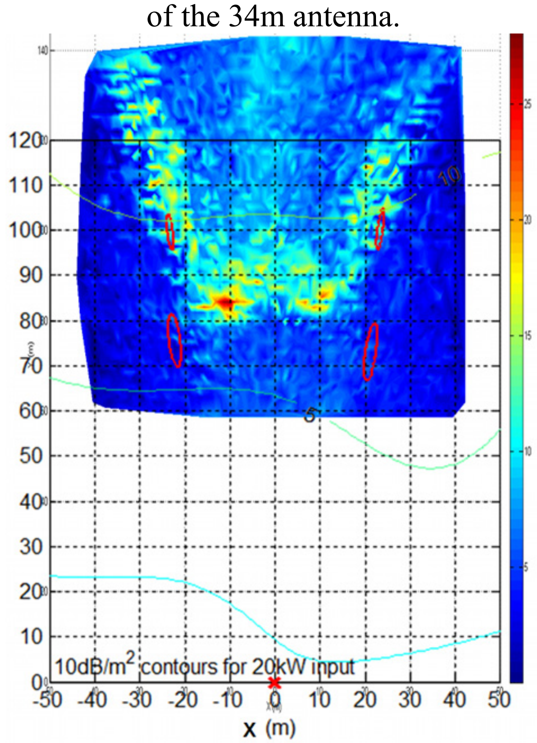

Fig.7(b).Measured results on the ground in front of the 34meter antenna

ACKNOWLEDGEMENT

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REFERENCE

[1] Veruttipong, T. ; Withington,.J.R. ; Galindo-Israel, V. ; Imbraile, W.A. ; Bathker, D.A ; "Design considerations for beamwaveguide in the NASA Deep Space Network

[2] V. Jamnejad, "A study of near to far fields of JPL Deep Space Network (DSN) antennas for RFI analysis," IEEE Aerospace Conference, Big Sky, Montana, March 6-13, 2004.

[3] GRASP 9.4-9.7, A general reflector antenna analysis software by TICRA Engineering Consultants, Copenhagen, Denmark.

[4] American National Standards Institute (ANSI), "Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz," ANSI/IEEE C95.1-1992.