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Analysis of axially displaced elliptical antenna using hybrid method

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Abstract

Axially displaced elliptical (ADE) antenna is an evolved version of Gregorian antenna, bearing advantages of minimized blockage and relatively uniform field distribution. However, the analysis of the electrical performance of this type of antenna is a difficulty to be addressed properly. To enable the simulation of such type of reflector antenna, a hybrid method is derived for predicting the farfield of ADE antennas. Closed formulae are firstly derived for the calculation of the near field of ADE antennas based on vector analysis and the law of energy conservation. These formulae avoid time-consuming surface current integration and the current singularity on the vertex of the sub-reflector. In addition, the nature of vector analysis makes the hybrid method be capable of predicting vector electric field precisely. Furthermore, since these formulae are in explicit manner, no ray tracing process is required. The farfield is then predicted using Huygens equivalent method, assuring the accuracy in the farfield. Compared to published experimental results in the literature, the proposed method agrees well with the measurement in the main beam region. In comparison to physical optic method, the computational efficiency is much improved.

Keywords ADE antenna, hybrid method, Huygens equivalent method

1 Introduction

ADE antenna has been widely used in a range of applications, such as in multi-beam system [1], and space communication systems [2–3]. In the general form, an ADE antenna consists of a main reflector, a sub-reflector and a feed horn. The surfaces of the main and sub-reflector are formed through rotation of a displaced parabolic curve, and a section of a tilt ellipse about the z-axis, respectively. In essence, ADE antennas are an evolutionary version of Gregorian antenna [4]. The benefits of this type of configuration are minimized blockage and relatively uniform near field distribution.

Nevertheless, the analysis of ADE antennas is a difficult task. Physical optics (PO) is usually employed to accurately predict the farfield of an electrically large antenna. However, due to the unique structure of the ADE antenna, PO cannot handle properly the issue of current discontinuity on the vertex of the sub-reflector. Normally, a spike is formed at the center of the sub-reflector of an ADE antenna. The spike usually causes singularity in current distribution. In consequence, abnormally large current can be observed using PO calculation. Incorrect simulation results have been observed using commercial simulation software GRASP. In addition, a few calculation methods such as method of moment (MOM) [5–6], hybrid method of mode analysis and MOM [7] have been utilized to predict the farfield of ADE antennas. Generally speaking, MOM is suitable for analysis of moderate electrically large system. For electrically large system, the main limitation is computational efficiency.

In this sense, we proposed a hybrid method by using the combination of the derived formulae and Huygens equivalent method to circumvent this problem. These derived formulae are employed to calculate the near field distribution over the aperture plane, while Huygens equivalent method analyzes the farfield pattern. It has to be stressed that in the hybrid method, vector analysis is performed taking into account of energy conservation and Snell's reflection law. Therefore, this hybrid method

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circumvented the abnormal current distribution (i.e. current singularity) on the vertex point of the ADE antennas. In consequence, it produces reasonable accurate near field distribution. The Huygens equivalent method is employed for farfield prediction due to its high precision of electromagnetic computation. Subsequently, the overall accuracy is safeguarded. In addition, comparing to conventional PO technique, the proposed method has much higher numerical efficiency. Compared to geometrical optics (GO), the hybrid method presents one with explicit formulae, which bypasses the process of ray tracing.

The remaining part of this paper is organized as follows: Sect. 2 details the geometry and parameters of ADE antennas. Sect. 3 describes the analysis method. Sect. 4 is case study. Sect. 5 summarizes this work.

2 The ADE antenna

The sectional configuration of an ADE antenna is schematically illustrated in Fig. 1. In Fig. 1, D and d are the diameter of the main dish and sub-reflector, respectively. F_1 and F_0 are the two foci of the ellipse. The feed is placed at F_0. V_1 is the vertex of the sub-reflector, while V_2 is the vertex of the parabolic curve. P_1, P_2, and P_3 are arbitrary points on the sub-reflector, main dish, and the aperture plane, respectively. f is the focal length of the parabolic. r is the distance of an arbitrary point on the aperture to z-axis. θ_0 is the angle between the longer axis of the ellipse and z-axis; θ_1 is the angle between F_0P_1 and z-axis; θ_2 is the angle between P_1P_2 and the longer axis of the ellipse and z-axis; and θ_3 is the angle between P_1P_2 and z-axis. The main reflector is formed through rotating a section of a parabolic about the z-axis. The focal point of the parabolic is F_1, with the focal length of f. The sub-reflector is formed through rotation of a section of a tilt ellipse. One focal point of the tilt ellipse coincides with that of the main reflector. The feed is placed at the other focal point of the tilt ellipse F_0. The angle between the long axis of the ellipse and z-axis is θ_0. The diameter of the sub-reflector is d, while the diameter of the main reflector is denoted as D. A hole with a diameter of d is formed at the center of the main reflector.

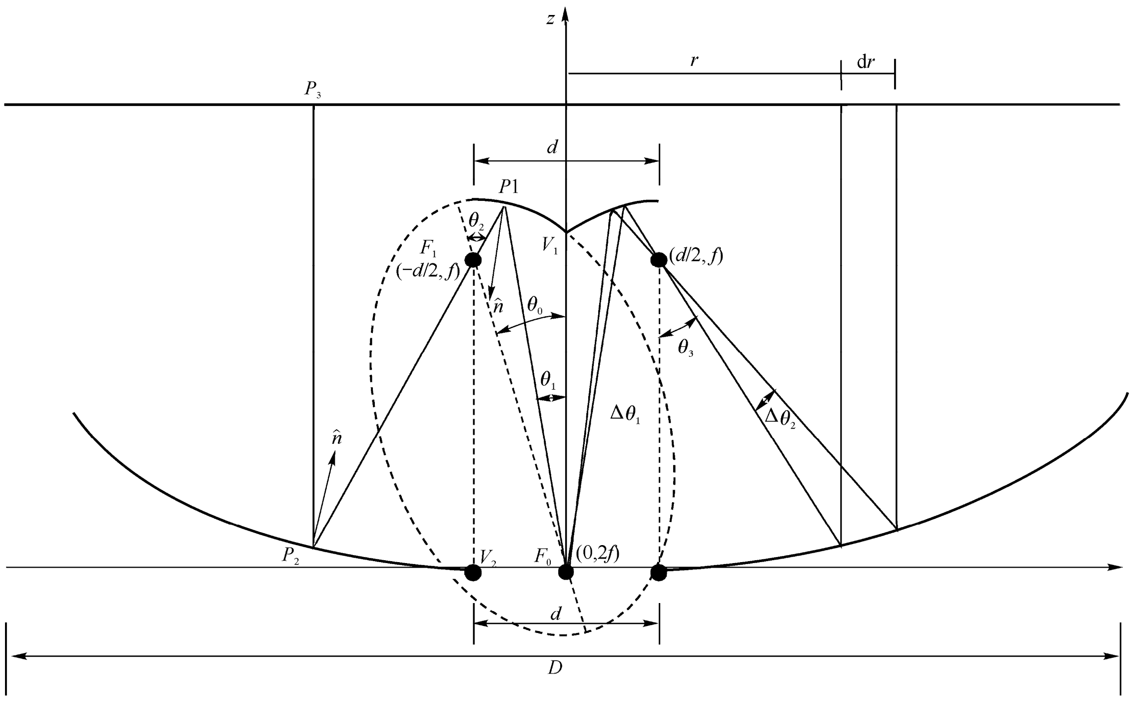

Fig. 1 The configuration of an ADE antenna and its parameters

Form the configuration of ADE antennas, it is clear that the ray incident on the central and edge parts of the sub-reflector will be reflected and directed to the edge and central region of the main reflector, respectively, as shown in Fig. 2. Therefore, the central rays with higher power density from the feed need to cover larger area than the lower-power-density edge rays do. Consequently, the amplitude distribution on the aperture will be more