Characteristics of the Large Adaptive Reflector Antenna Fed by Paraboloid Reflector

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A-Introduction

A novel feed system for a Large Adaptive Reflector (LAR) [1], was proposed in [2], and [3] which may be used in high gain antenna applications such as deep space communication and radio telescope. The LAR consists of a large and almost flat paraboloid reflector of the diameter in excess of 200 m, that is slightly adjustable in shape and made up of identical flat panels supported by actuators on the ground. A very large focal length-to diameter ratio (2.5) imposes the unusual condition that the receiver or sub-reflector be carried by an airborne vehicle such as tethered aerostat as shown in Fig. 1. The LAR is in general an offset paraboloid which is intended to have a wide angle beam scanning of around $\pm 60^{\circ}$.

This new feed systems consists of a symmetric paraboloid reflector with a diameter of 25 m to feed a 5 ~10 m Hyperboloid sub-reflector located 500 m from its vertex as shown in Fig. 2. Due to the large aperture size of the paraboloid feed reflector, the sub-reflector would be located in its Fresnel region, which demands the feed focus on its near field. It is well-known that a paraboloid reflector can focus to Fresnel region by defocusing its horn feed. Utilizing the aperture field integrals, introduction of the quadratic phase error resulting from the defocusing of the horn antenna away from the Feed-Reflector surface, on its aperture field, brings the far field radiation pattern of the Feed-Reflector to the focal field region of main LAR reflector.

In this paper, characteristics of the above mentioned three reflector system are considered. Effects of the defocusing distance, d_f, and the sub-reflector magnification, M, over the system performance are also investigated.

B-Three Reflector System Performance

The geometrical parameters of a the LAR system with a paraboloid Feed-Reflector are shown in Fig. 2. The field taper at the Feed-Reflector edge, T_a, is considered to be -15 dB, d_f= 0.23 m f_F =9 m (Feed-Reflector focal length). The sub-reflector diameter, D_S, is chosen to be 5 m, $2c$ = 500 (foci distance) and M = 48.62. The influence of these parameters on the LAR performance are discussed later. The effect of blockage is taken into account by removing the central portion of the LAR, the radius of which is 15 m, or 15% of the LAR radius. The operating frequency is assumed to be 3 GHz. The radiation pattern of the system is shown in Fig. 3. The efficiency of the system is 72.% which is related to a directivity of 74.52 dBi at 3 GHz. The half power beamwidth, HPBW, is 0.03°. The diffraction cross-polarization (horn feed is assumed to be ideal and have no cross-polarization) and first side lobe level are -71 dB and -19 dB below maximum directivity respectively, which are in acceptable ranges.The sub-reflector field induces a taper of -9.5 dB at the edge of LAR, while the taper at its edge due to the Feed-Reflector is -13 dB. In this calculation the effect of the Feed-Reflector parasitic fields on LAR radiation pattern is taken into account. This parasitic fields are due to the current induced by the sub-reflector on the Feed-Reflector. It is observed that the Feed-Reflector radiation pattern has impact only on the sidelobes which are located at least 10 beamwidth away from the main lobe.

The radiation pattern for the sub-reflector at the place of the LAR is depicted in Fig. 4. This figure shows a field taper of -9.5 dB at LAR edge. A phase distribution with maximum 12^{o} variation on the LAR is observed. The dip in the middle of the sub-reflector radiation pattern reliefs the effect of sub-reflector on the Feed-Reflector and reduce its parasitic fields.In Fig. 5 the gap in the middle of LAR aperture distribution is due to the Feed-Reflector blockage. The field taper at the LAR aperture edge is -15 dB which is equal to feed horn taper at the Feed-Reflector edge. The LAR Phase distribution shows about 0.07λ phase error across the LAR aperture.

C- Effect of Defocusing Distance, d_f and Sub-reflector Magnification, *M*

Fig. 6 shows the radiation patterns of the Feed-Reflector with D_F = 25 m, f_F = 9 m, and T_a = -15 dB, at the sub-reflector (D_S = 5 m, 2*c* = 500 m, *M* = 48.17) location which is located in the Fresnel region of the Feed-Reflector, for different values of its feed defocusing d_f at 3 GHz. The maximum field intensity occurs when d_f= 0.23 m. This value also provides the maximum efficiency for the LAR as shown in Fig.7. Fig.8 shows the effect of feed defocusing on the LAR sidelobe level (SLL) and cross-polarization. which indicates that d_f=0.23 m provides minimum SLL, and cross-polarization for LAR.It has been shown in [4] that, the defocusing value is independent of the operating frequency. This property was examined by the results of simulation at 5 GHz for aforementioned Feed-Reflector and sub-reflector and T_a = -40 dB.Again maximum efficiency of 70% occurs at d_f=0.23 m.

The sub-reflector magnification determines the curvature of the sub-reflector, and as a result that portion of LAR which must be illuminated. The results of different magnification values, on the LAR gain are shown in Table 1. To obtain these results a 5 m diameter sub-reflector is considered. Parameters of the Feed-Reflector are D_F=25 m, and d_f=0.23 m, with a field taper of -15 dB at the Feed-Reflector edge, 2*c* = 500 m and the operating frequency 3 GHz. The first row in this table shows the magnification of a sub-reflector for a classic Cassegrain design, which is different from the optimum magnification of this system with Feed-Reflector.

D-Conclusion

A new feed system for Large Adaptive Reflector antenna was designed based on the near field focusing properties of the paraboloid reflector antennas. The effect of the horn feed defocusing distance of the Feed-Reflector and sub-reflector magnification over LAR radiation characteristic were studied. An efficiency of 72% with unshaped surfaces was obtained at 3 GHz.

D-References

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[4] D. K. Cheng, "On the simulation of Fraunhofer radiation patterns in the Fresnel region," *IRE Trans. Antennas Propagat.*, vol. AP-5, pp. 399-402, Oct. 1957.

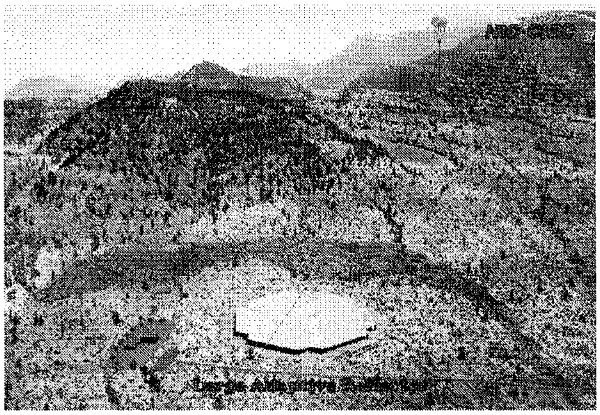

Fig.1: Large Adaptive Reflector Antenna

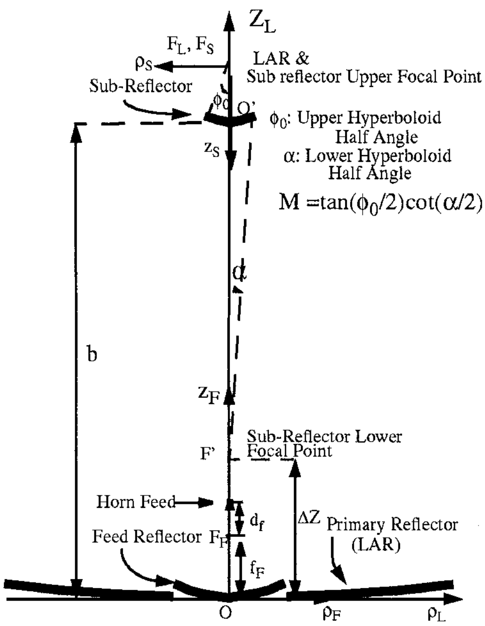

Fig. 2: Cross section of LAR Cassegrain system (Not scaled)

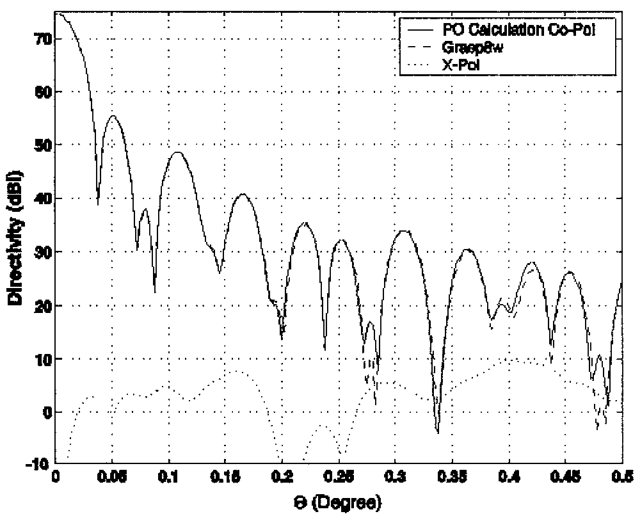

Fig. 3: LAR radiation patterns

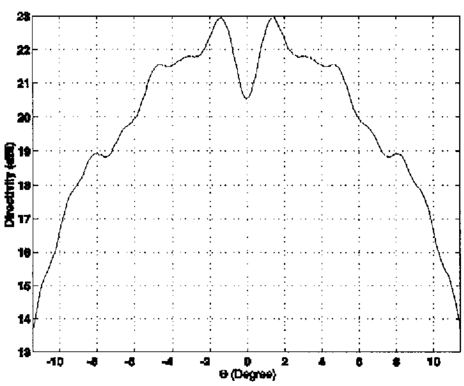

Fig.4: Sub-reflector radiation pattern at the LAR place

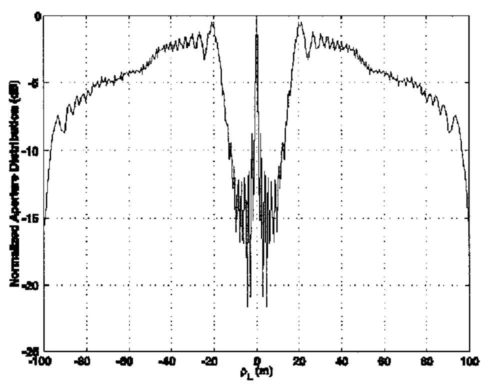

Fig. 5: LAR aperture distribution

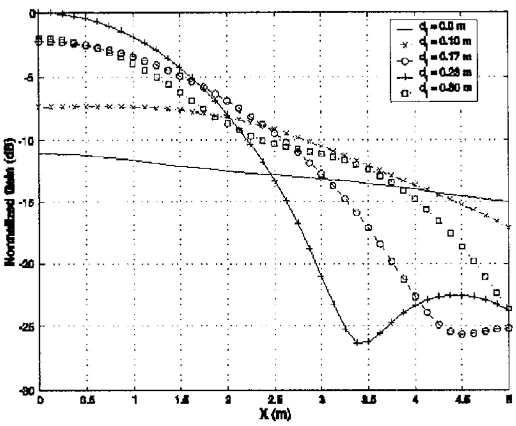

Fig. 6: Normalized near field radiation pattern of Feed-Reflector antenna at sub-reflector location

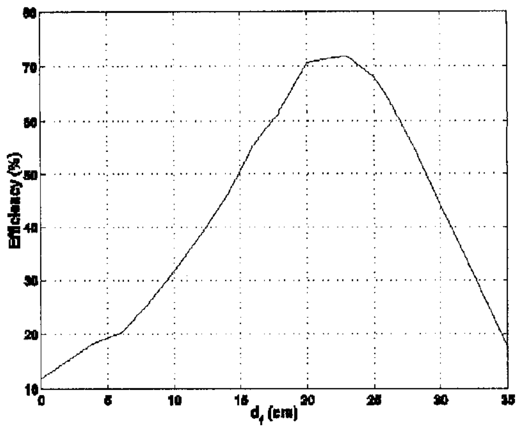

Fig. 7: LAR efficiency versus horn feed location

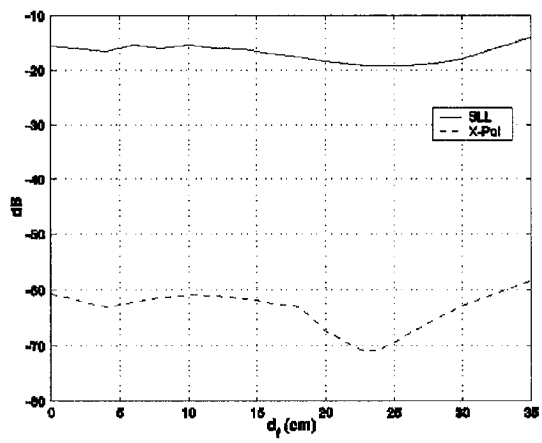

Fig.8: LAR sidelobe level and cross-polarization versus horn feed location d_f

Table 1: Effect of the sub-reflector on magnification on the LAR performance

M	ϕ_o(degree)	Efficiency%	SLL(dB)	X-Pol (dB)	LAR TAPER (dB)
39.46	11.42	64.4	-20.85	-66.95	-19.5
41	12.0	67.45	20.15	68.5	-17.5
44.48	13.0	70.63	-19.45	-71.2	-12.5
46.45	13.5	71.6	-19.26	-71.81	-10
48.62	14.0	72.0	-19.04	-71.74	-9
51.0	14.5	71.78	-18.92	-71.02	-10.5
52.28	15.0	70.63	-18.85	-70.35	-12.5

($M = \tan(\phi_0/2)\cot(\alpha/2)$, Fig. 2)