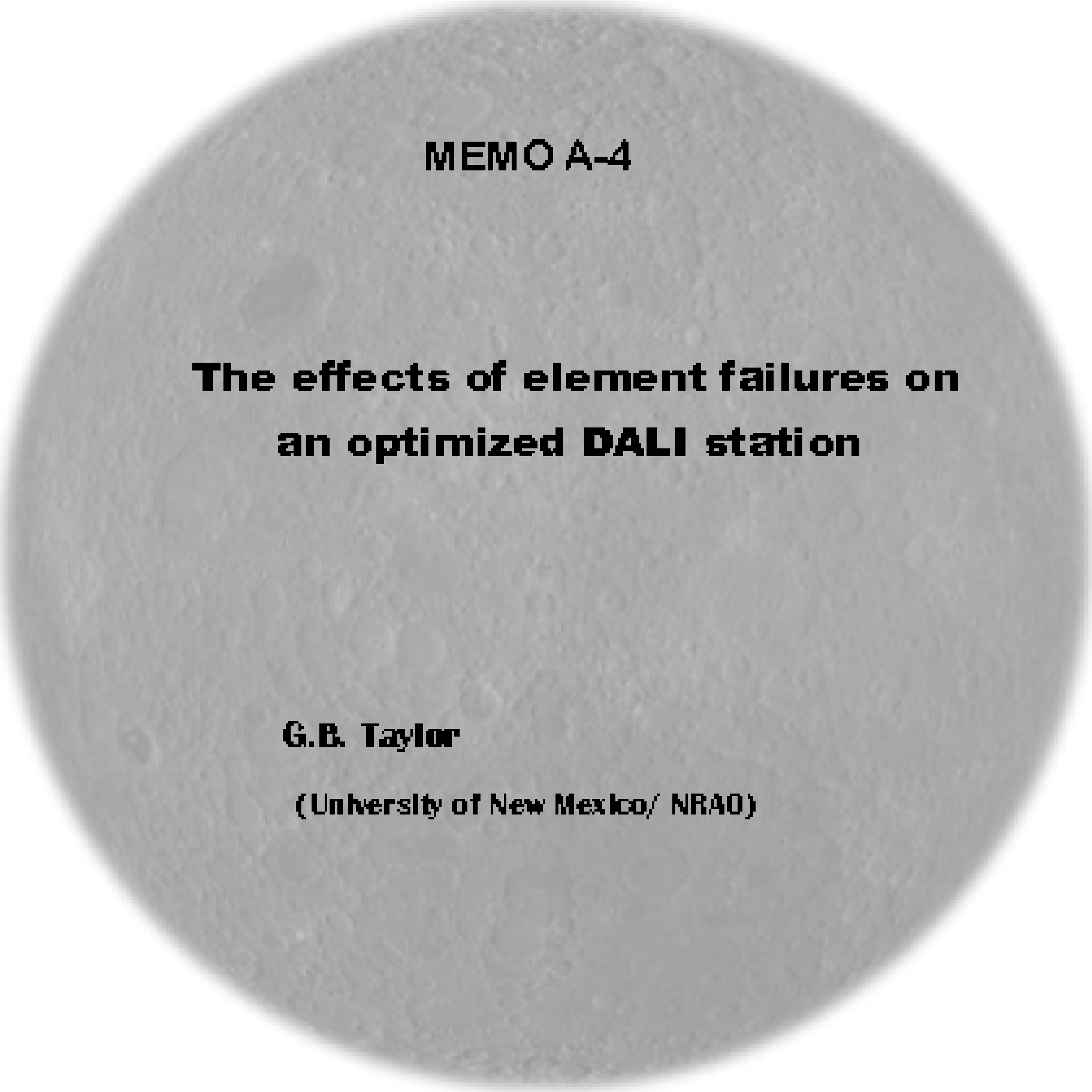
Lunar University Network for Astrophysics Research

MEMO SERIES



MEMO A-4

The effects of element failures on an optimized DALI station

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LUNAR memo # 4

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ABSTRACT

The goal of this report is to explore robustness of the array design for the Dark Ages Lunar Interferometer (DALI) to failures of individual elements within a single station. Understanding how a station responds to failures is critical as it is likely that visits to repair stations may be infrequent, or even nonexistent. We apply the same algorithm of optimization as in previous work. This is an array configuration minimizing side lobes designed by Leonid Kogan. We consider several scenarios for failure including random and systemic failures. We find that while the degredation from random failures if fairly slow, systemic failures of large groups of elements in the same part of the array are much more serious.

1. Introduction

The Dark Ages Lunar Interferometer (DALI) is a telescope designed to study highly-redshifted neutral hydrogen (HI) signals from the Universe's *Dark Ages*, namely, the epoch between recombination and the formation of the first luminous objects. The array is assumed to be placed on the far side of the moon, and to have no radio interference (of either solar or human origin) by observing during the long lunar night. The array is assumed to be observing at zenith so that no dimunition of the collecting area occurs by projection. The array is assumed to consist of N roughly circular stations of diameter, D, distributed over a flat surface. The stations are comprised of M dipoles which can be used to form B beams on the sky. These beams are transmitted to a central location, or to the Earth, for correlation. The final product of the array is visibility measurements which can be transformed to create images or analyzed directly. The deployment of the array is assumed to be carried out by one or more rovers. For more details of the array design see Taylor & Rodriguez (2009).

Understanding how the array responds to failures is critical as it is likely that visits to repair the staton may be infrequent, or even nonexistent. We apply the same algorithm of optimization as in previous work, which is to minimize the maximum sidelobe levels at zenith. We explore

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robustness with a large ($M = 991$) number of dipoles and a station diameter of 120 m. No attempt is made to model the effects of mutual coupling, and the dipole power pattern is assumed to be Gaussian. We consider both random and systemic failures of elements and then recompute the beam shape and sidelobe levels.

2. Random Failures

We first consider the effect of random failures of individual elements. Such failures might be the result of defective components at installation, or the gradual effects of micro-meteorites or other unforeseen failure modes. The random failure of individual elements will have two effects: (1) a loss of sensitivity proportional to the number of elements lost; (2) a degredation of the beam shape from that obtained with the complete, optimized array. It is the latter effect that is the more difficult to write down an analytic expression, but the simulation is straight-forward.

In Fig. 1 we show the optimized configuration, and in Fig. 2 the resulting beamshape (point-spread-function). From this configuration we randomly remove 1%, 3%, 10%, 20%, and 50% of the dipoles. In Table 1 we give the resulting sidelobe level. We find that the maximum sidelobe level increases gradually up to 0.00926 (-20 dB) from 0.00147 (-28 dB). In Figs. 3 and 4 we show the configuration and beam shape for the worst case (50% loss).

3. Systematic Failures

We next consider the loss of groups of antennas. Such a loss might be caused by an installation issue with a roll of antennas, or a failure mode that breaks the lines of communication to a set of antennas.

From the optimized configuration we removed 3% and 10% of the elements in roughly linear swaths. Results are tabulated in Table 1. A 3% systemic loss appears worse than a 20% random loss, and a 10% systemic loss is worse than a 50% random loss. In the worst case considered here, the 10% systemic loss results in the first sidelobe level of 0.02236, or -16 dB, an increase of 12 dB over the optimized level. In Figs. 5 and 6 we show the configuration and beam shape for the worst case that we considered (10% loss).

4. Summary and Future Plans

We have demonstrated that the beamshape (point-spread-function) of the stations is robust to random failures of individual elements. Even the failure of 50% of the stations causes an increase in the sidelobe level of just 8 dB. Loss of this many elements would reduce the sensitivity of the station by a factor of 2. Systematic failures of groups of elements are more serious and the failure of 10% of the elements in this way increases the first sidelobe level by 12 dB over the optimized value.

The simulations presented here are only approximate and do not take into account important considerations such as mutual coupling and the power pattern of the elements. Observations with the first LWA station should be of considerable interest as the reveal the degree to which mutual coupling influences the station-level optimization. Another area of study for the future is to include realistic toplogical constraints for a specific site.

We thank Leonia Kogan for instructions on how to use his CONFI task for the configuration simulations.

REFERENCES

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Table 1. Results of Element Failures

Number of antennas	Maximum sidelobe level (%)	comment
919	0.00147	the optimized station
911	0.00178	1% random loss
892	0.00214	3% random loss
827	0.00216	10% random loss
735	0.00282	20% random loss
459	0.00926	50% random loss
893	0.00460	3% systematic loss
828	0.02236	10% systematic loss

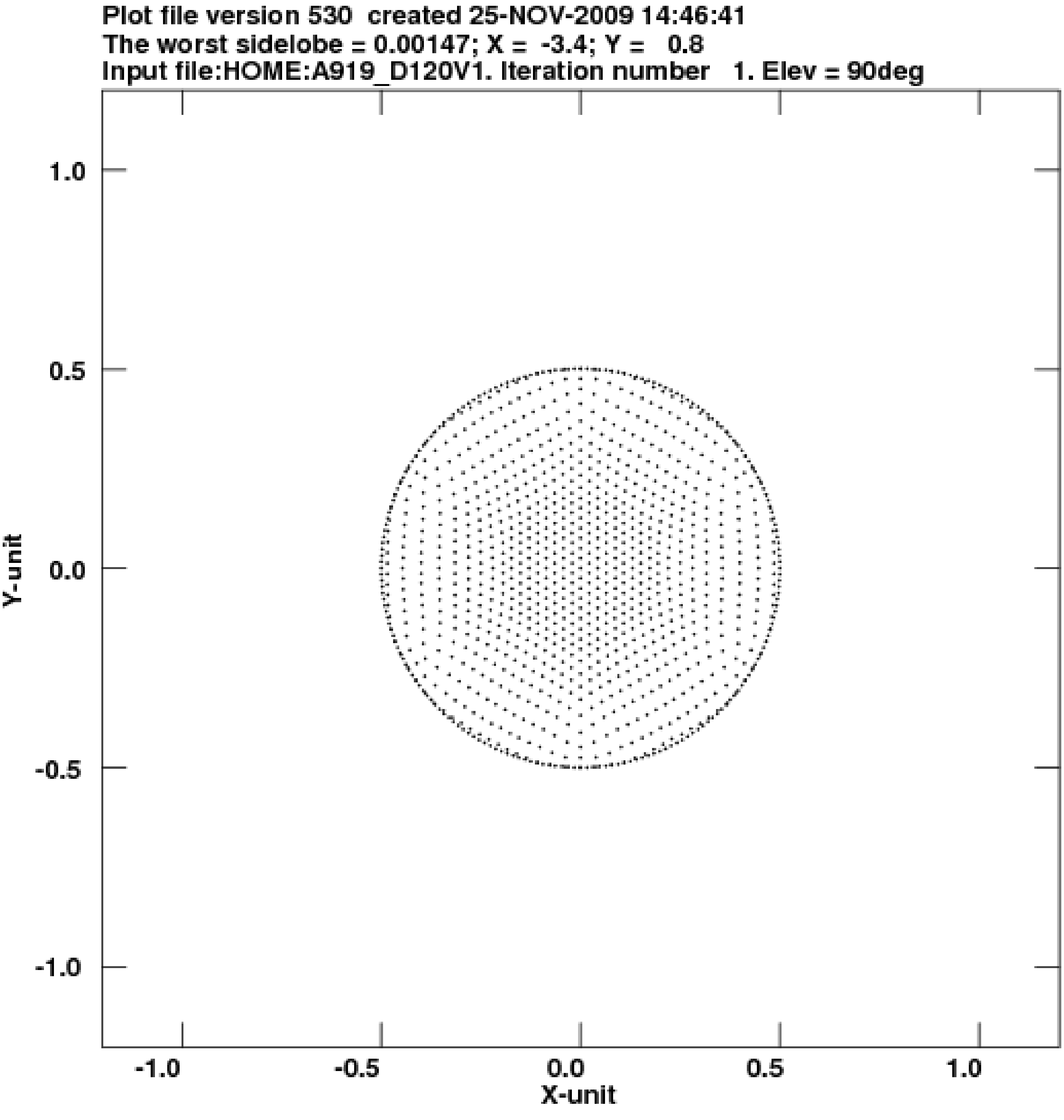

Fig. 1.— Optimized hexagonal station configuration used as a starting point for the analysis. There are 919 antennas inside a circle of diameter 120 m. A minimum spacing of 3 m between the elements was used.

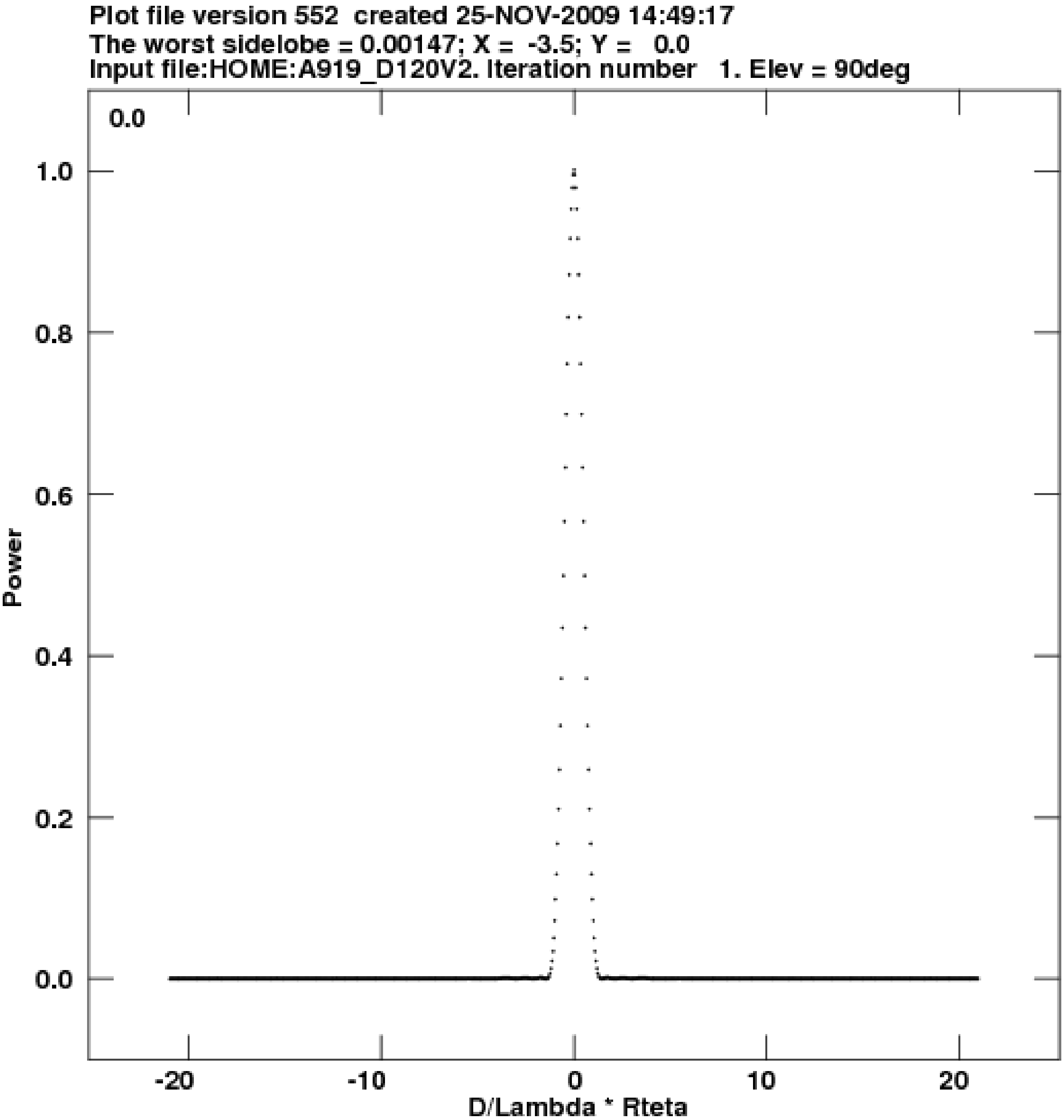

Fig. 2.— Beam pattern for the optimized 919 element configuration shown in Fig. 1.

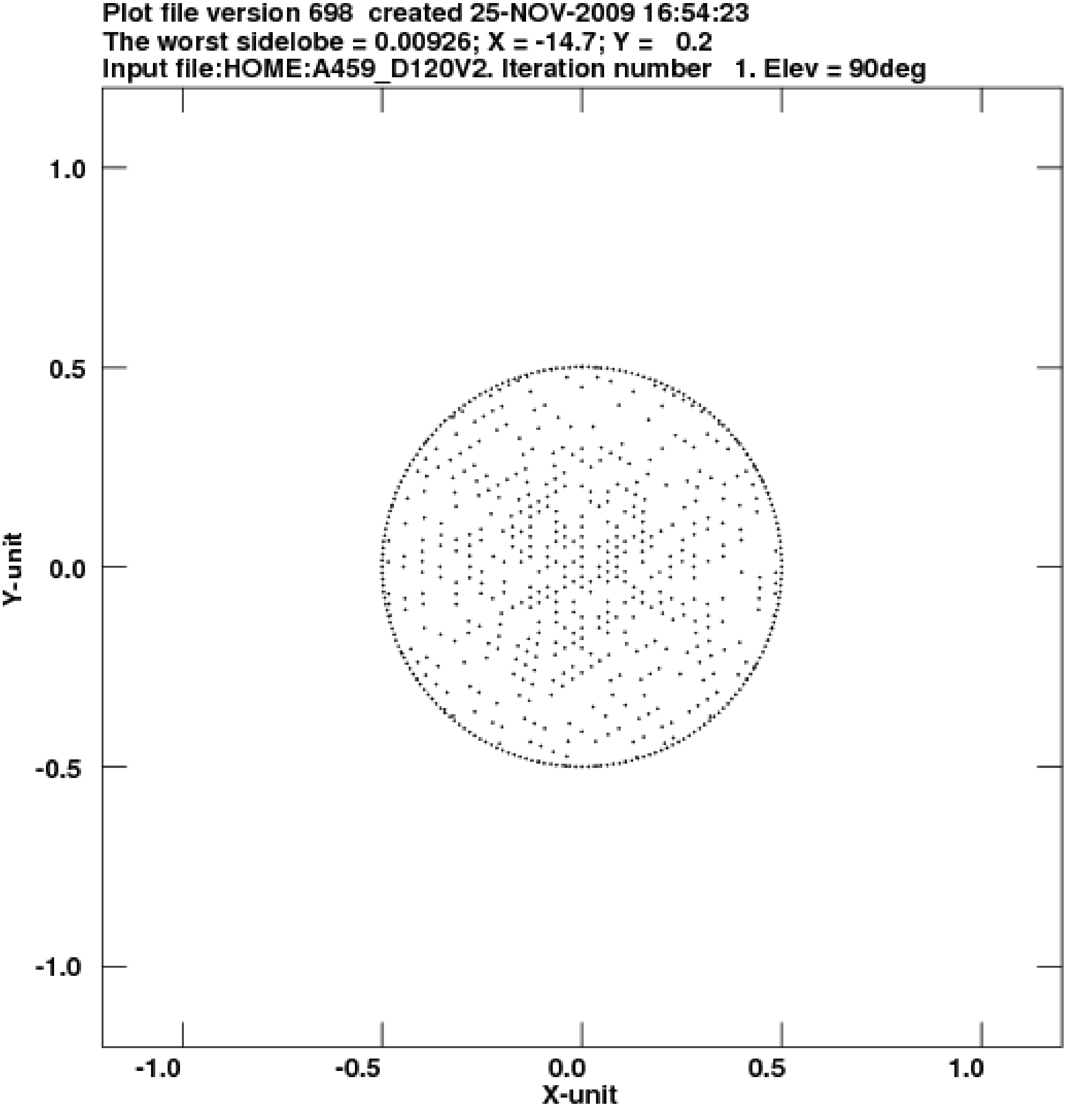

Fig. 3.— Optimized hexagonal station configuration after the random failure of 50% of the elements.

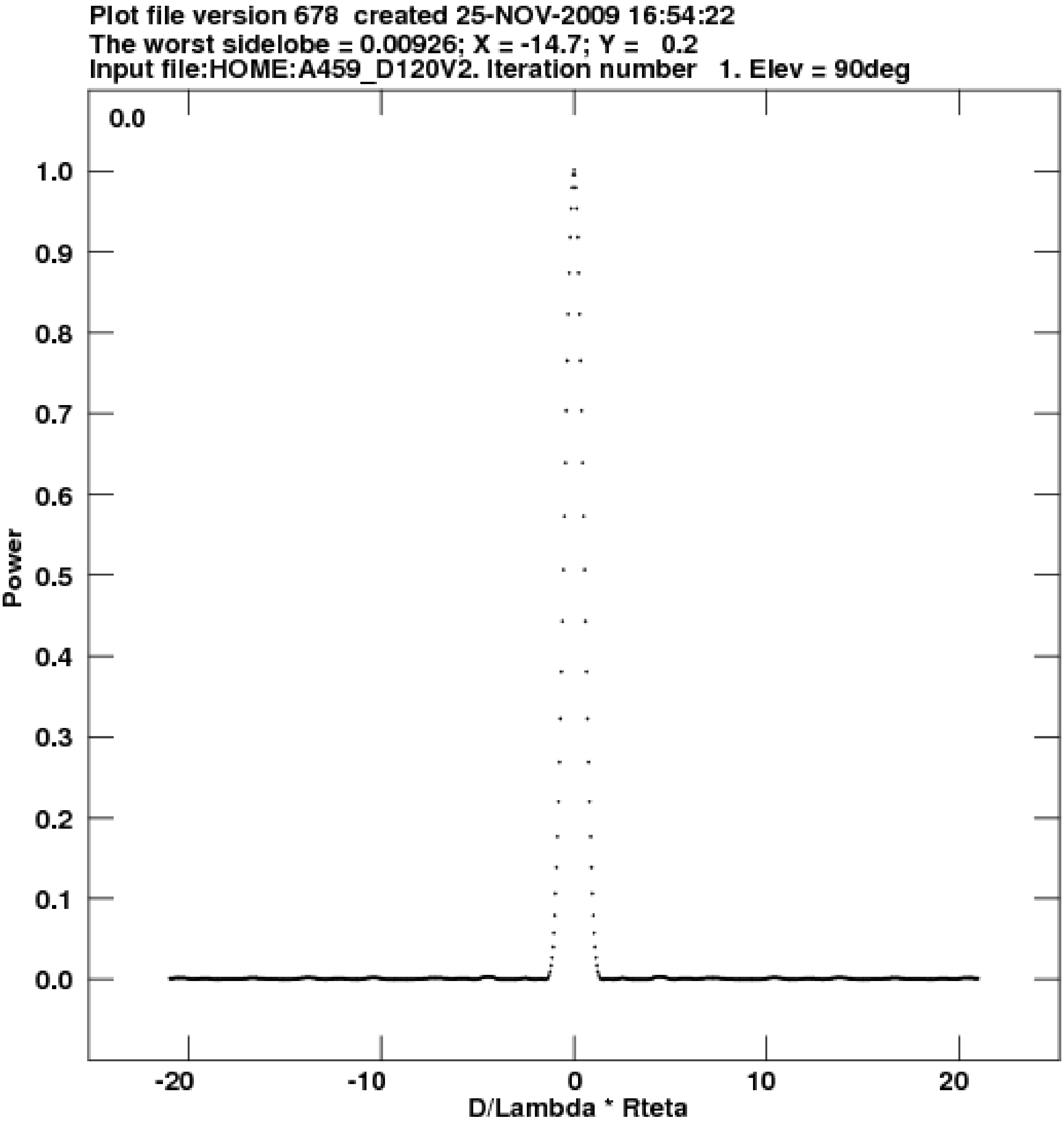

Fig. 4.— Beam pattern for the 459 element configuration shown in Fig. 3.

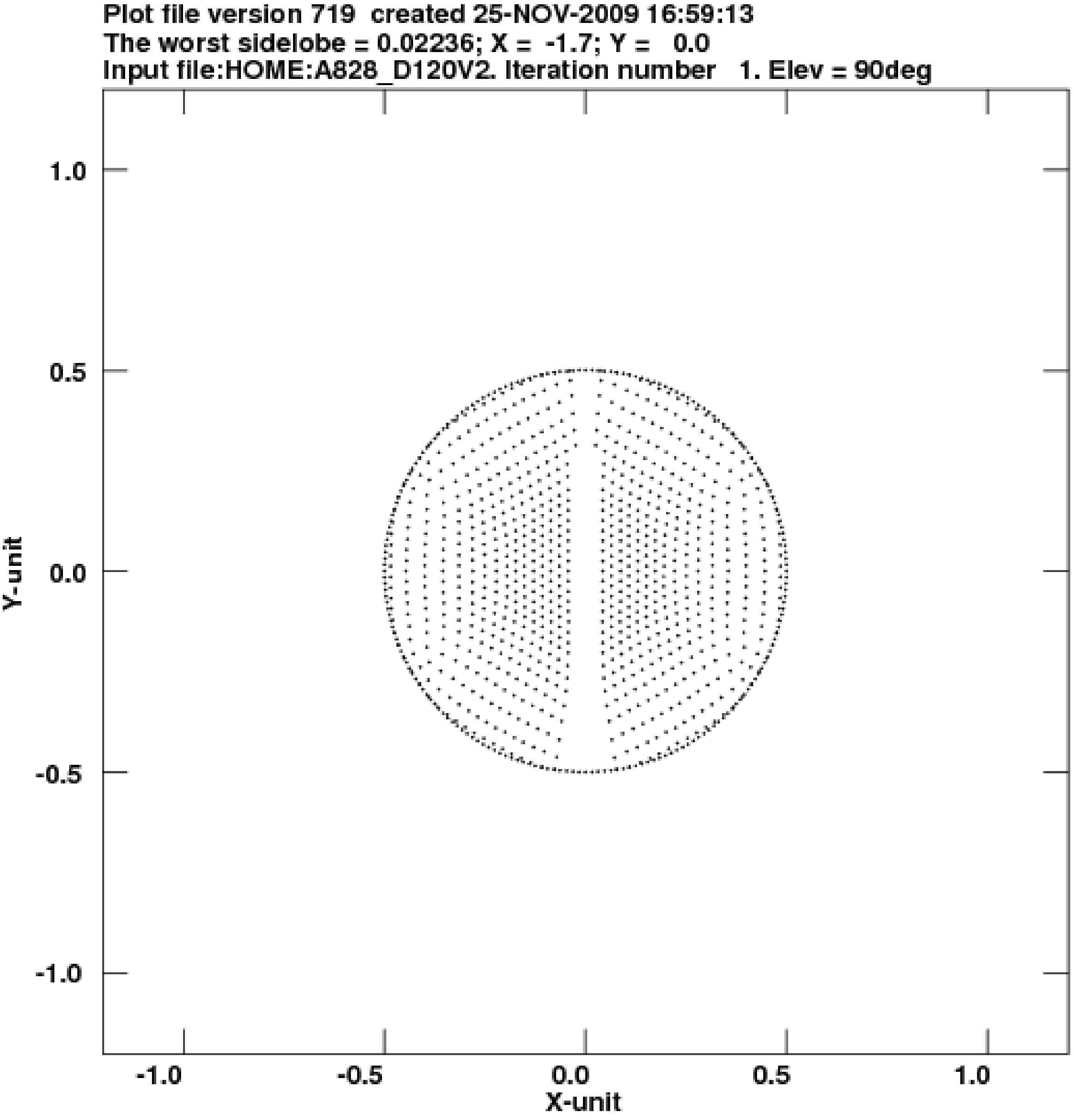

Fig. 5.— Optimized hexagonal station configuration after the systematic failure of 10% of the elements.

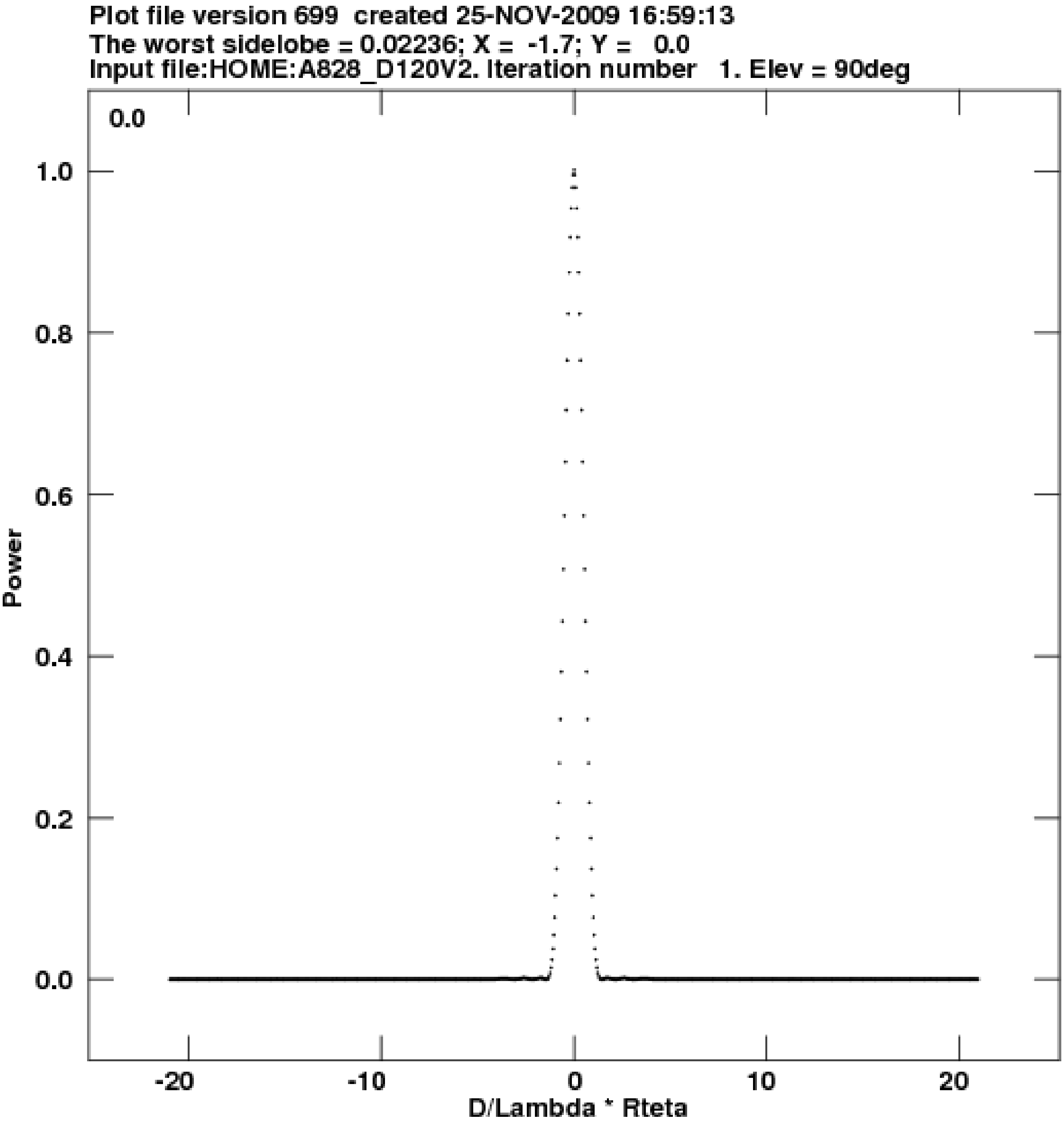

Fig. 6.— Beam pattern for the 828 element configuration shown in Fig. 5.