

## Spatial suppression of interference in hybrid reflector antennas \*

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**Abstract.** The article describes a 7-beam hybrid reflector antenna with a 19-element feed element which forms a radiation pattern in the form of a cluster. During the research the synthesis of the amplitude-phase distribution of the antenna feed element has been conducted. A radiation pattern for three situations of interference: along the first side lobe, along the ramp of the main lobe, along the main lobe.

**Keywords:** hybrid reflector antenna, special filtering, interference, adaptive algorithms, antenna radiation pattern

### 1. Introduction

Currently, more attention is paid to the issue of satellite communication systems in Russia. The primary reason for this is the necessity to prove reliable communication to distant areas of the country: especially for the underpopulated areas of Siberia, Yakutia, the Far East, and the Russian Arctic. Considering the unequally populated territory of Russia (the majority of the population resides in the European part of the country or in southern areas of Siberia) and the large number of time zones, it is necessary to include a flexible control system for the communications channels. This flexibility is basically a traffic redistribution system, which functions depending on the load. Another factor for developing such a system is the high concentration of radiating radio-electronic devices in the industrial parts of the country: this often causes problems with electromagnetic compatibility. There are many cases when industrial interference caused malfunction in satellite communication systems. This makes it urgent to include interference protection for communications channels in all new satellite communications systems.

Among the more perspective methods for solving this problem is the utilization of multibeam adaptive phased antenna arrays for an onboard antenna. By retargeting the beams, these antennas enable effective flexible control of the traffic. Also they can provide special filtering by controlling the radiation pattern: forming maximums targeted at the source of the signal and minimums at the source of interference. However, multibeam adaptive phased antenna arrays have a number of disadvantages. They are quite expensive – this is due to the

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complex production process for these devices, they have a large mass and are take up much space, the amplification coefficient is low. Hybrid reflector antennas with adaptive phased antenna arrays for a feed element are possessed of these disadvantages to a lesser extent. Utilizing hybrid reflector antennas in spacecraft in comparison with adaptive phased antenna arrays is more perspective – especially in terms of lower costs and reduction of weight – due to higher requirements to the amplification coefficient of the antenna system (exceeding 35 – 40 dB) [1]. In this case, to construct an adaptive phased antenna array a large number of elements from 90 to 255 is necessary for a radiation pattern of  $2^\circ \times 2^\circ$  и  $1^\circ \times 1^\circ$ . This results in significant in the increase of productions costs (up to 4 times) and mass (80 to 100 kg). The construction of the array also becomes overengineered. Adaptive hybrid reflector antennas have lesser scanning angles, however for geostationary spacecraft this factor is not a significant disadvantage and is substituted by the simpler design and lower mass (30 – 40 kg).

One of the main problems for building adaptive multibeam hybrid reflector antennas is the design of methods and algorithms to spatial adaptiveness to interferences. In [2–5] an algorithm for synthesizing amplitude-phase distribution of hybrid reflector antennas has been designed. This algorithm considers the features of both adaptive phased antenna arrays and reflector antennas.

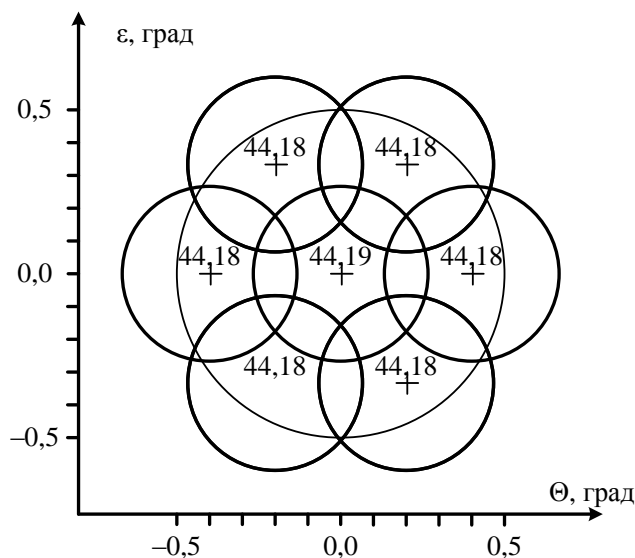
## **2. Modelling the synthesis method for amplitude-phase distribution of a radiating array of a hybrid reflector antenna during interference**

Let's consider an adaptive multibeam antenna based on a hybrid reflector antenna. This antenna consists of a mirrored reflector and feed element in the form of a 19-element antenna array that generates 7 beams of the radiation pattern on the basis of a cluster. Each cluster, consisting out of 7 feed elements is powered cophasally: half of the radiated power is transmitted on to the central feed element and half is transmitted to the peripheral feed elements [1, 2].

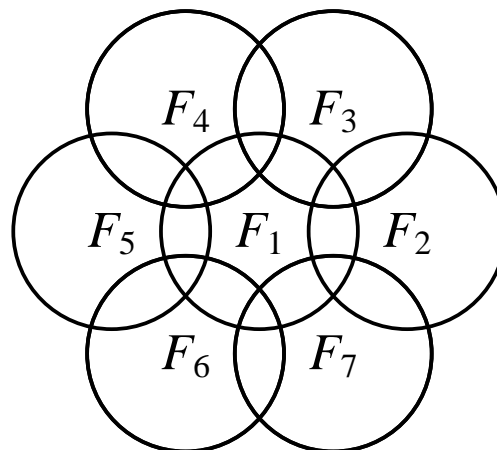
Let's perform a modelling of the amplitude-phase distribution of a radiating array of a hybrid reflector antenna during interference. The radiation pattern of the adaptive hybrid reflector antenna is calculated using GRASP 9.3.03 and SATSOFT software. This software is certificated and verified for performing calculations of the radiation pattern for antennas.

The results of calculating the radiation pattern for a  $K_u$  band hybrid reflector antenna is shown in Fig. 1. The thin line shows the required service zone  $1^\circ \times 1^\circ$ .

To provide independent functioning of each beam of the adaptive hybrid reflector antenna, a frequency division is arranged between the beams (Fig. 2). Dividing the beams with seven frequencies is the most convenient: it enables to get an interbeam discrimination between 25 and 39 dB and fully eliminate the influence of beams on one another both in the mode when interference is absent and the suppression mode.



**Figure 1.** Covering the service area with asset of beams. Performance amplitude is 43.5 GHz; amplification coefficient for maximum radiation pattern of focal beam is 44.19 dB; amplification coefficient for maximum radiation pattern of peripheral beam is 44.16 dB.



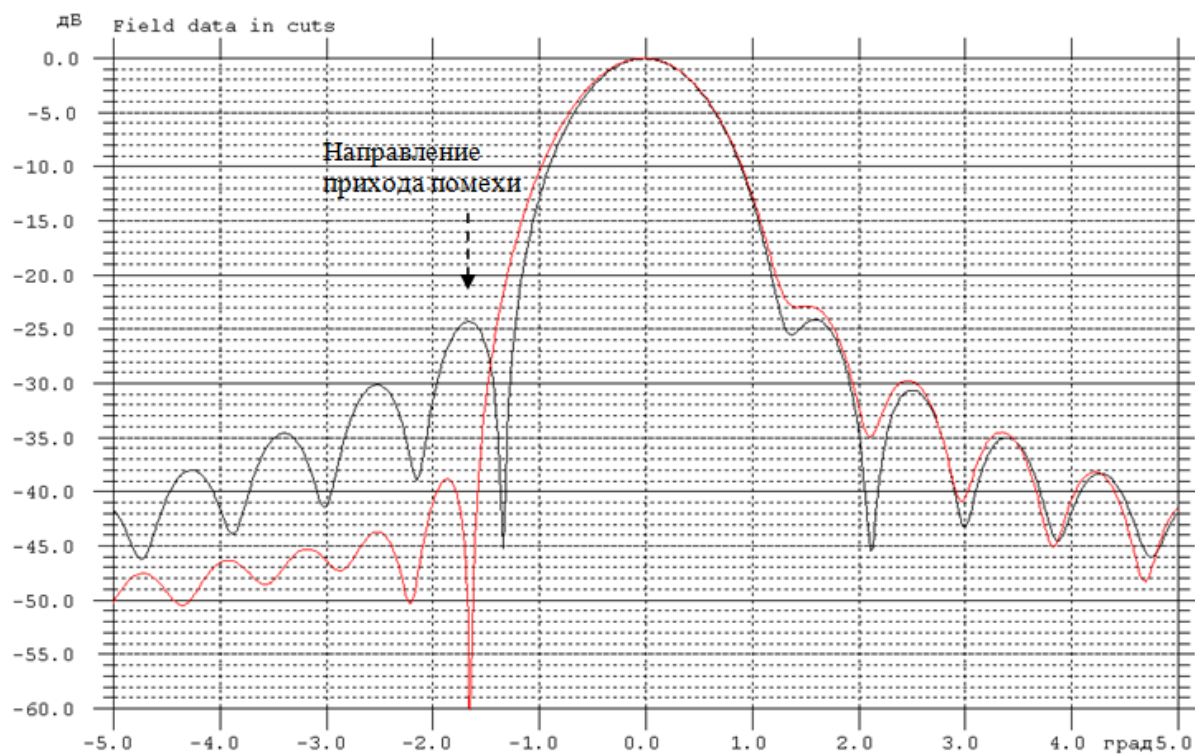
**Figure 2.** Frequency division between adaptive hybrid reflector antenna beams.

Let's perform calculations for interference suppression based on the proposed radiation pattern synthesis method in [4, 5]. The calculation is performed for the central beam of the adaptive hybrid reflector antenna. Since each beam of the antenna functions independently, similar results are achieved for the rest of the beams.

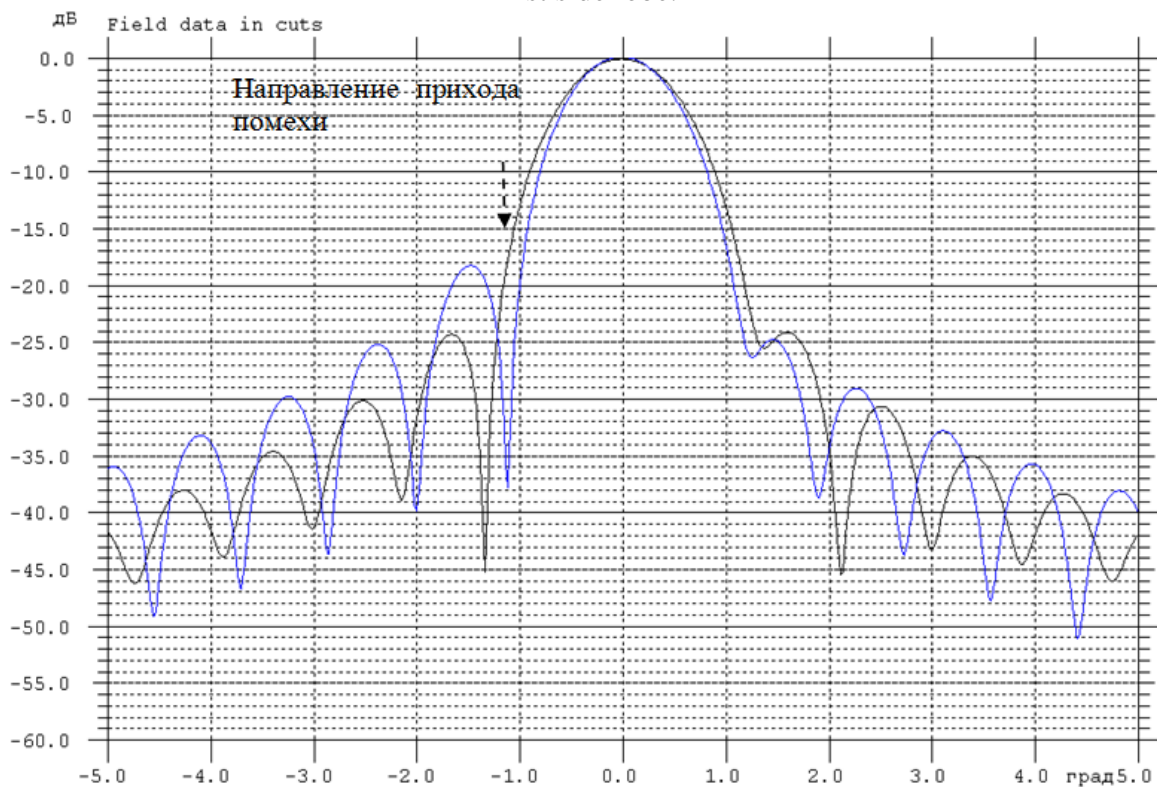
Figs. 3 – 5 demonstrate the synthesis results of amplitude-phase distribution of a radiating array of a hybrid reflector antenna. Its calculated radiation patterns are shown in Table 1. Synthesis of the radiation pattern is performed for three cases of directing interference effect:

- interference in direction of the first side lobe of the antenna;
- interference in direction of the ramp of the main lobe of the antenna;
- interference in direction of the main lobe of the antenna.

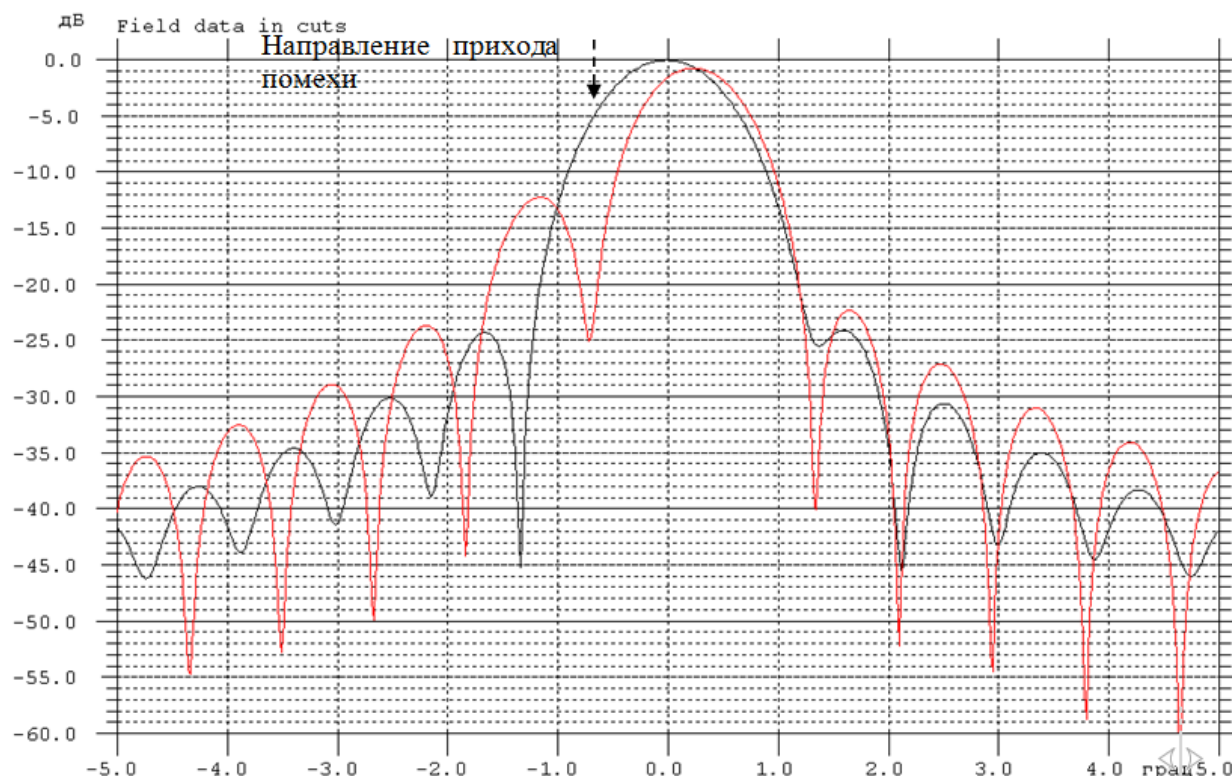
To synthesize the amplitude-phase distribution cluster, which consists out of 7 elements approximately 400 iterations of the algorithm were required, the number of points for the amplitude-phase distribution synthesis is 16. The position of the interference was determined by the program.



**Figure 3.** Results of radiation pattern synthesis for interference suppression in direction of first side lobe.



**Figure 4.** Results of radiation pattern synthesis for interference suppression in direction of ramp of main lobe of radiation pattern.



**Figure 5.** Results of radiation pattern synthesis for interference suppression in direction of main lobe of radiation pattern.

**Table 1.** Results of amplitude-phase distribution synthesis for radiation pattern.

Number of feed element	Direction of interference effect					
	First side lobe		Ramp of main lobe		Main lobe	
	Amplitude dB	Phase, grad	Amplitude dB	Phase, grad	Amplitude dB	Phase, grad
1	-5.33	-2.84	-2.54	-177.85	-6.39	-171.04
2	-7.72	1.08	-34.6	-171.74	-13.26	12.01
3	-10.88	0.32	-7.3	178.22	-5.19	145.05
4	-8.65	0.65	-11.86	-179.73	-8.09	161.23
5	-10.23	0.05	-14.58	-165.55	-13.36	-150.72
6	-8.49	1.01	-10.19	-164.82	-9.36	-125.02
7	-10.79	1.14	-12.19	-164.37	-9.86	-75.31

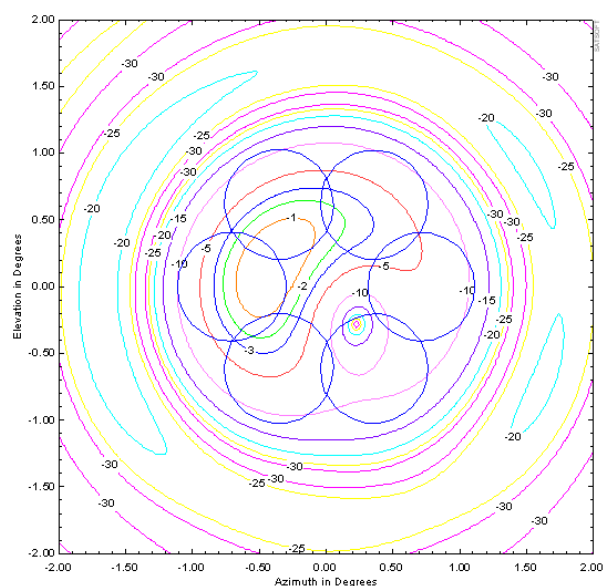
The calculation results for the radiation pattern of an adaptive hybrid reflector antenna demonstrate that during interference suppression in direction of the ramp of the main lobe the level of interference decreases to minus 25 – 35 dB while the signal level remains unchanged in the rest of the service area. During interference suppression in direction of the main lobe of the radiation pattern, a reduction in the amplification coefficient to 1 dB is observed; the interference suppression level is recorded at minus 25 dB – a satisfactory result for satellite communications systems.

For the given scheme of adaptive hybrid reflector antenna arrangement it is possible to

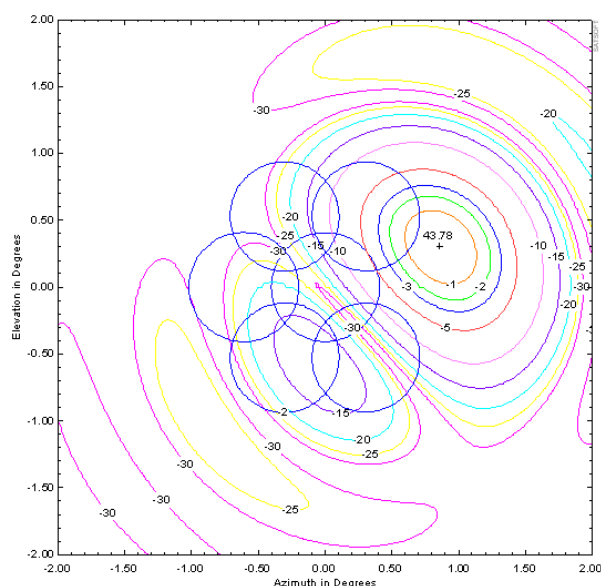
utilize a functioning mode in which each antenna beam will suppress interference independently from the other beams. Since each antenna beam is formed by seven feed elements the amplitude-phase distribution synthesis will enable interference to be suppressed in a similar to the 7-element cluster way. This method is optimal considering the system's effectiveness in whole and signal level maintenance for the remaining service area.

Let's suppose that we are sure of the interference positions in advance. Since the beams function independently from one another and are divided by frequency, an amplitude-phase distribution synthesis for the 7-element cluster is performed for each beam to suppress interference.

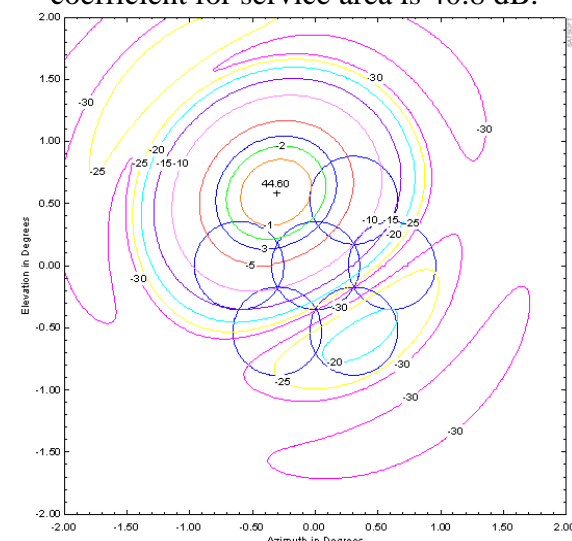
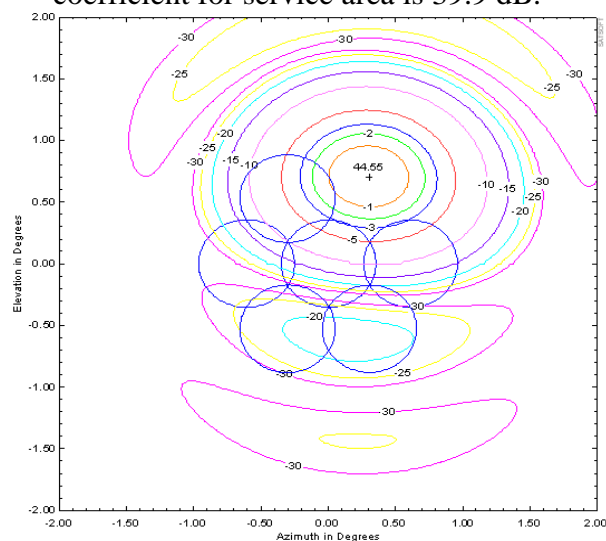
Figs. 6 – 11 demonstrate the modelling results for suppressing interference for each beam of the adaptive hybrid reflector antenna, the neighboring beams without interference adaptiveness.



**Figure 6.** Interference suppression by beam No. 1. Amplification coefficient at maximum radiation pattern is 42.47 dB. Amplification coefficient for service area is 39.9 dB.

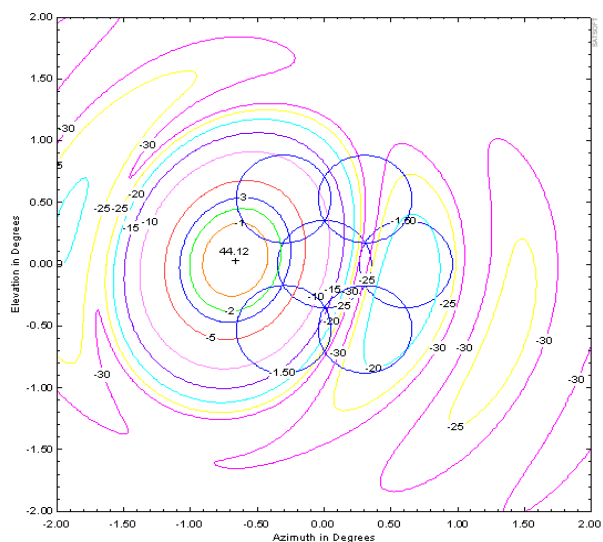


**Figure 7.** Interference suppression by beam No. 2. Amplification coefficient at maximum radiation pattern is 43.78 dB. Amplification coefficient for service area is 40.8 dB.



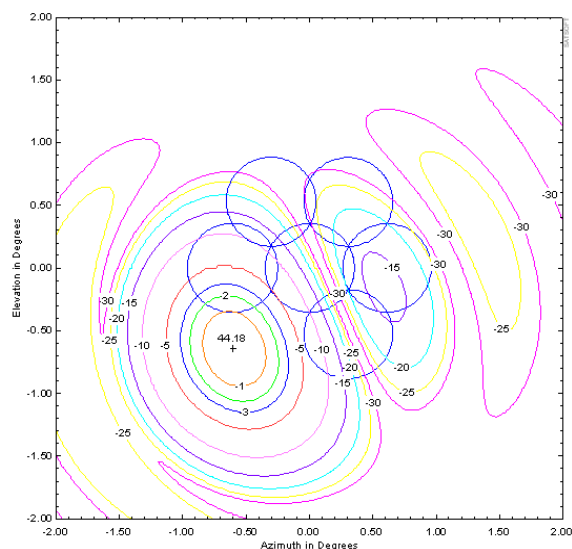


**Figure 8.** Interference suppression by beam No. 3. Amplification coefficient at maximum radiation pattern is 44.55 dB. Amplification coefficient for service area is 41.5 dB.



**Figure 10.** Interference suppression by beam No. 5. Amplification coefficient at maximum radiation pattern is 42.12 dB. Amplification coefficient for service area is 41.1 dB.

**Figure 9.** Interference suppression by beam No. 4. Amplification coefficient at maximum radiation pattern is 44.6 dB. Amplification coefficient for service area is 41.6 dB.



**Figure 11.** Interference suppression by beam No. 6. Amplification coefficient at maximum radiation pattern is 44.18 dB. Amplification coefficient for service area is 40.2 dB.

### 3. Conclusion

A radiation pattern for suppressing interference to a level of minus 40 dB in relation to the radiation pattern maximum has been constructed for each beam of an adaptive hybrid reflector antenna, built on the cluster scheme, using the results of the amplitude-phase distribution synthesis. The signal level for the remaining service area was 39.9 dB for the worst beam.

Due to the frequency division of the beams, the adaptiveness of the given seven beams will not influence the neighboring beams since the radiation pattern has high amplitude for decreasing signal level. This provides required a discrimination between beams with the same frequency.

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