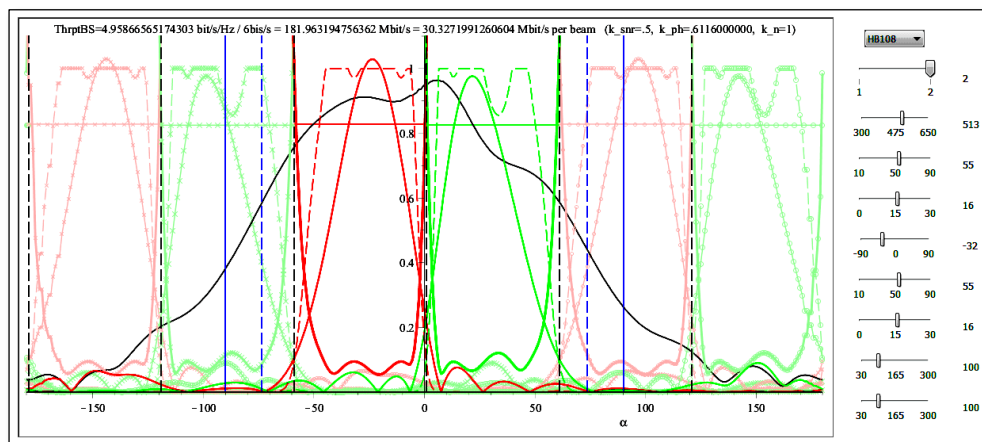


MassMIMO Antenna Design Suite

Quick overview and application examples

v.1.15F



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Contents

1. Quick Overview	3
2. Example of "Result" Window	4
3. Application Example 1: LTE TM4/TM9 Solution for eNB.....	5
4. Application Example 2: Massive MIMO Antenna for LTE and 5G NR Base Stations	6
5. Application Example 3: Taking into Account Interelement Couplings, Couplings between Elements and Antenna Structure, and Providing a Design with Very Close to Real Product Characteristics	7
6. Application Example 4: Cylindrical Massive MIMO Antenna	8

1. Quick Overview

MassMIMO Antenna Design Suite is software aimed

- to synthesize the optimal beam radiation pattern and MIMO / massive MIMO antenna construction for increasing throughput, coverage, user satisfaction, and other key network parameters;
- to optimize beamforming and MIMO / massive MIMO algorithms;
- to provide link-level simulation taking into account all antenna parameters able to affect the network performance (construction, real radiation patterns of antenna elements, interelement couplings, etc.);
- to provide computer antenna system design with characteristics that will be very close to the characteristics of the further real product.

Examples (for details refer to the Application Example sections):

- **Beamforming developed by MassMIMO Antenna Design Suite has improved performance of an LTE solution by 25-85%.**
- **Massive MIMO antenna designed by MassMIMO Antenna Design Suite has significantly reduced the number of elements and width (that means cost, wind load, and mass), and at the same time improved most of the main characteristics.**

MassMIMO Antenna Design Suite allows

- to design equidistance, non-equidistance, and non-flat antenna arrays (including cylindrical);
- to choose the optimal antenna configuration (number of elements, columns, and rows, element positions, interelement distances, antenna surface shape, type of array elements, etc.);
- to use the tailor-made beam technique (for adjusting beam radiation patterns to optimize target characteristics);
- to take into account interbeam and interantenna interference at the same base station;
- to use 3GPP as well as custom specified scenarios for link-level simulation.

2. Example of "Result" Window

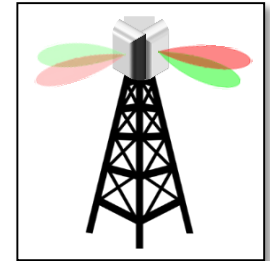
Base station (BS) and scenario configuration

Base station:

3 antennas at 120°, 2 beams per antenna (multibeam cellsplitting), antenna type – massive MIMO array 8(rows)x5(cols)x2(pols), array element type – HB108

Scenario:

Customized 3GPP TR 36.873 3D-UMa (7 BSs, BS distance 500 m, 30 UEs per 120° sector, channel model and user distribution – 3D-UMa)



A screenshot of the Suit's "Result" Window for this BS and scenario configuration is presented in Fig. 2-1.

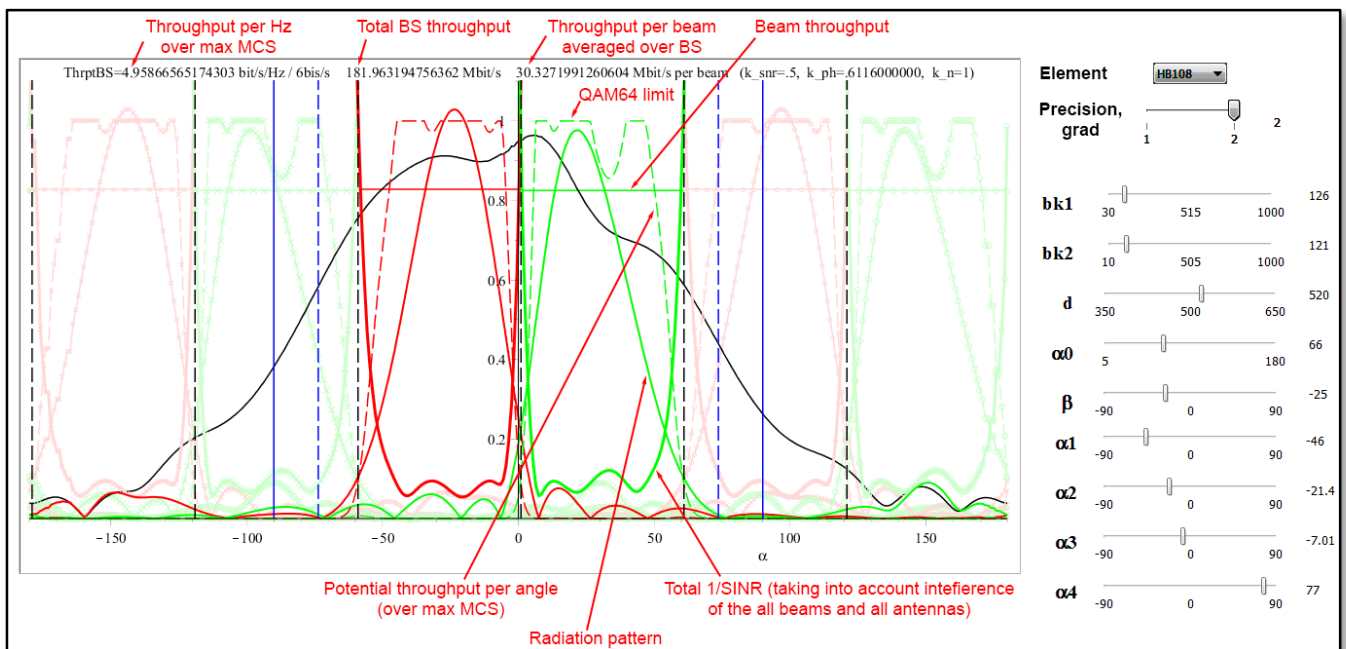


Fig. 2-1. Screenshot of "Result" Window

- light-red lines with crosses – antenna 1 beam 1
- light-green lines with crosses – antenna 1 beam 2
- red lines – antenna 2 beam 1
- green lines – antenna 2 beam 2
- light-red lines with circles – antenna 3 beam 1
- light-green lines with circles – antenna 3 beam 2

- black solid line – array element radiation pattern
- blue solid lines – radiation pattern mirror boundary 1
- blue dash lines – radiation pattern mirror boundary 2
- black dash lines – beam boundaries calculated by SINR

3. Application Example 1: LTE TM4/TM9 Solution for eNB

The simulation results of the TM4/TM9 solution developed in the frame of the project to update Huawei's eNB equipment are presented in Table 3-1. The new solution is based on the modern tailor-made beam technique and designed by **MassMIMO Antenna Design Suite**. The **Suite** has helped to essentially increase network performance. For example, the throughput of the new solution in TM4 is 26% (for Suburban Macro 3GPP TR 25.996 scenario) and 70% (for 3D-UMa 3GPP TR 36.873 scenario) higher than the current solution provides even in TM9. **The results appear more significant if take into account that TM9 is more modern and advance than TM4, moreover TM9 uses uplink information and Zero Forcing algorithm that TM4 cannot.**

The examples of tailor-made beams are presented in Fig. 2-1 (Screenshot of Result Window) in the previous section. Non-symmetric main-beam and side-lobe shapes are optimized to provide maximal network performance.

Table 3-1. NetLab simulation results for downlink sector throughput, MB/s

Scenario	Current solutions						New solution designed by the Suite	
	TM4	TM9					TM4	TM9
	40TRx 8x5 4 ports multibeam cellsplitting	40TRx 8x5 4 ports	40TRx 8x5 8 ports	40TRx 8x6 4 ports	40TRx 8x6 8 ports	48TRx 8x6 8 ports	40TRx 8x5 4 ports multibeam cellsplitting	40TRx 8x6 8 ports
SM	44.3	49.2	55.6	54.1	57.5	61.6	62.2	76.7
3D-UMa	42.3	41.5	43.4	42.9	44.0	47.3	70.6	80.8

SM – Suburban Macro 3GPP TR 25.996 scenario.

3D-UMa – 3D-UMa 3GPP TR 36.873 scenario.

AAS – active antenna system.

AAS configuration decoding:

8x6 means rectangular phased antenna array consisting of 8 rows x 6 columns,

40TRx means 40 digital channels,

4 ports means 4 antenna ports as defined in 3GPP TS 36.211.

4. Application Example 2: Massive MIMO Antenna for LTE and 5G NR Base Stations

Massive MIMO antenna designed by **MassMIMO Antenna Design Suite** has a significantly reduced number of the elements and the width (that means cost, wind load, and mass), and at the same time better characteristics (Table 4-1).

Table 4-1.

Comparison of the massive MIMO antenna designed by the Suite with the previous solution

	Previous solution (8x6 equidistant)		Solution designed by the Suite (8x4 non-equidistant)		Comparison of the previous solution vs the new one designed by the Suite	
	Rural	Urban	Rural	Urban	Rural	Urban
Number of elements	48		32		-33% (better)	
Antenna width, m	0.40		0.31		-22% (better)	
Sector throughput, MB/s	41.5	39.8	44.8	39.1	+8.1% (better)	-1.7% (worse)
at 0.05	0.41	0.30	0.46	0.36	+11.2% (better)	+18.7% (better)
at 0.5	1.12	0.95	1.16	0.99	+3.3% (better)	+4.1% (better)
at 0.9	2.21	2.22	2.44	2.32	+10.1% (better)	+4.6% (better)
Interference over Thermal, dB	31.2	36.0	28.4	31.7	-2.8 (better)	-4.3 (better)

Notes

1. The antennas are aimed to operate at the frequency bands: n7, n30, n34, n38, n40, n41, n53, n90, n95 (according to 3GPP TS 38.104).
2. Both antennas use the same antenna elements.
3. **8x6 (8x4)** means rectangular phased antenna array consisting of 8 rows x 6 columns (8 rows x 4 columns).

5. Application Example 3: Taking into Account Interelement Couplings, Couplings between Elements and Antenna Structure, and Providing a Design with Very Close to Real Product Characteristics

Interelement couplings in antenna array and couplings between array elements and antenna structure can significantly reduce key array characteristics relative to the theoretical values due to changing element radiation patterns (refer to Fig. 5-5). The radiation pattern changes are not the same for all elements but depend on the position in the array. Moreover, if there is even only one element its radiation pattern essentially depends, for example, on the position relative to the reflection surface center. It means that the radiation patterns of all elements are different.

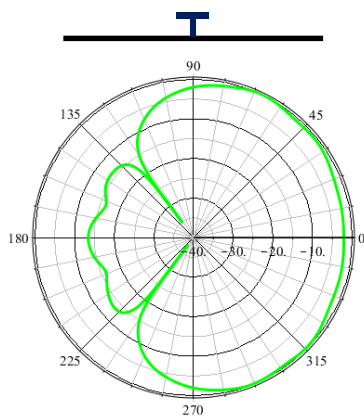


Fig. 5-1. Radiation pattern of the element placed in the reflector center (HFSS simulation)

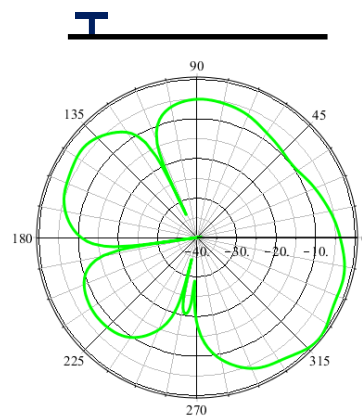


Fig. 5-2. Radiation pattern of the element placed at the reflector border (HFSS simulation)

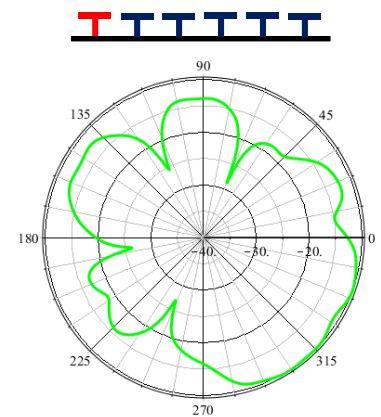


Fig. 5-3. Radiation pattern of the border element inside of the 6 element array (HFSS simulation)

MassMIMO Antenna Design Suite allows to take into account a real element radiation pattern, interelement coupling, and couplings between array elements and antenna structure, thus synthesizing the beam radiation pattern that is very close to real product.

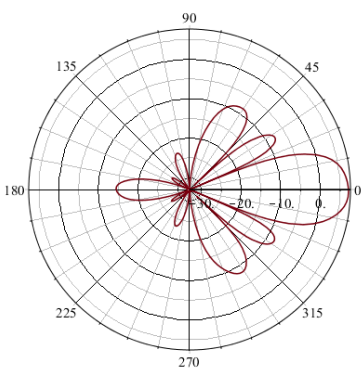


Fig. 5-4. Theoretical radiation pattern of the array simulated using the radiation pattern of the centrally placed element (Fig. 5-1).

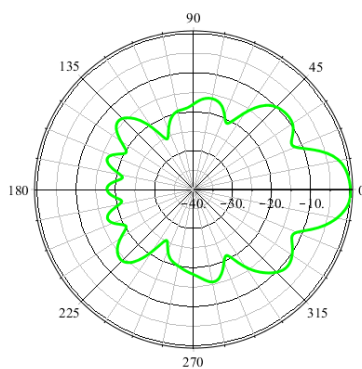


Fig. 5-5. HFSS simulation of the array with the theoretical radiation pattern shown in Fig. 5-4. **The radiation pattern is significantly worse than the theoretical one shown in Fig. 5-4.**

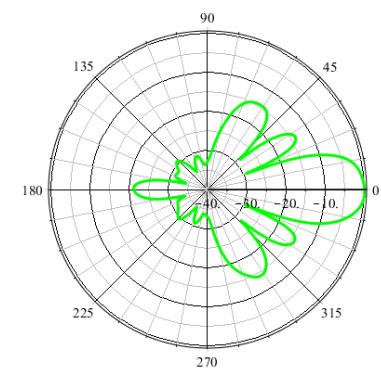


Fig. 5-6. HFSS simulation of the array with the radiation pattern synthesized by **the Suite** with taking into account interelement couplings. **The radiation pattern is very close to the theoretical one shown in Fig. 5-4.**

6. Application Example 4: Cylindrical Massive MIMO Antenna

Non-flat antenna array has a number of advantages. In particular, the beam width is approximately inversely proportional to the aperture size visible from beam direction (Fig. 6-1). It means, the more angle between beam direction and array surface perpendicular the beam wider. Along with the beam width, other antenna characteristics are also degrading. Non-flat array is able to provide optimal characteristics for any direction (Fig. 6-2). That is especially important for base stations because they have to provide a wireless connection for full azimuth angle 360°.

Most methods to design array structure and radiation pattern (for example, Dolph-Chebyshev, Kaiser-Bessel, Barcion-Themes windows, etc.) are developed only for a single beam flat equidistant array with isotropic elements. If any of the conditions is not applicable, these methods cannot provide a good result. It is shown, for example, in the book *D.I. Voskresenskiy, A.I. Kanaschenkov, Active Phased Arrays* (Fig. 6-3). This figure shows that the radiation patterns synthesized by the conventional methods have a high sidelobe level in comparison with a flat array of the same size.

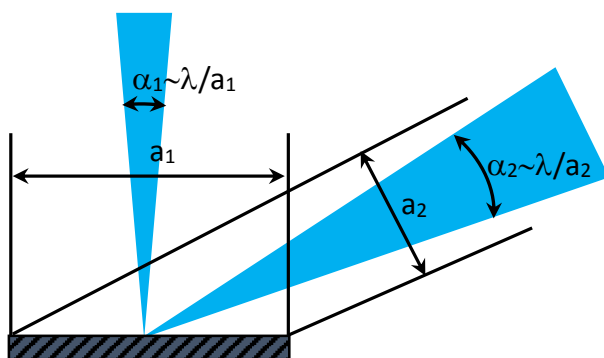


Fig. 6-1. On the beam width estimation

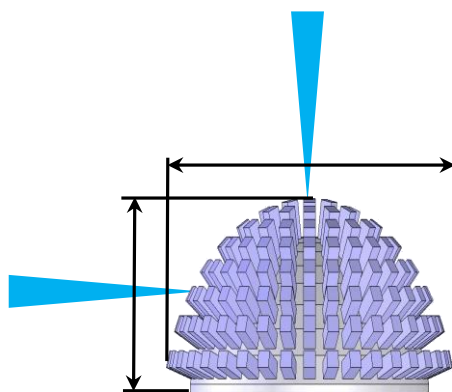


Fig. 6-2. Due to non-flat array can have the same visible aperture from any direction inside the operating sector, the beam width and other characteristics can be strong in the whole sector.

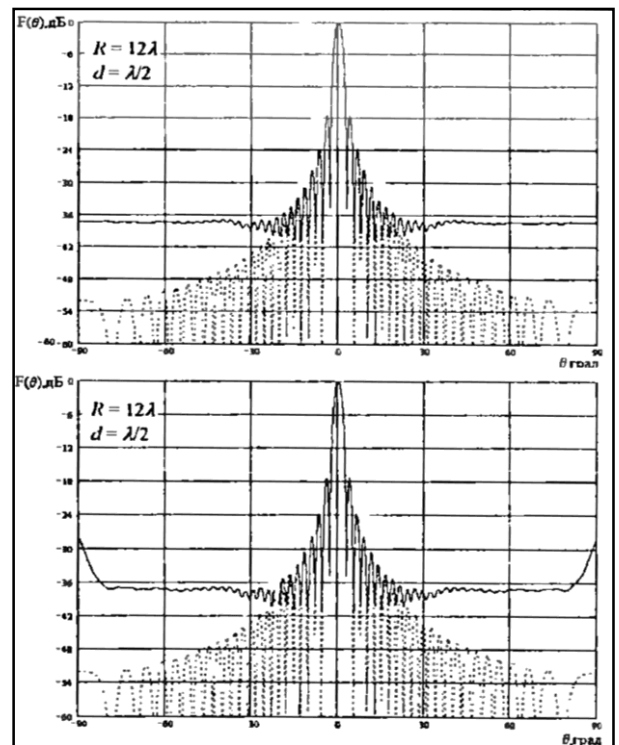


Fig. 6-3. Comparison of the radiation pattern of a semispherical array (solid lines) with the flat array of the same size (dash lines).

Figure from the book *D.I. Voskresenskiy, A.I. Kanaschenkov, Active Phased Arrays // Radiotekhnika, Moscow, 2004.*

IZMIRAN (institute of Russian Academy of Sciences) started to develop methods for non-flat/non-equidistant/non-isotropic-element arrays more than 10 years ago. Since this time, a set of methods has been developed for designing such types of arrays, and they demonstrated high results in hardware implementation. Key methods have been included in **MassMIMO Antenna Design Suite**. It allows using this **Suite** to create high efficient designs for various complicated antenna arrays including the mentioned above.

An example of the radiation pattern synthesized by **MassMIMO Antenna Design Suite** for semicircle array (Fig. 6-4) is presented in Fig. 6-5. This figure demonstrates the ability of **MassMIMO Antenna Design Suite** to synthesize for non-flat array the high efficient radiation pattern with sidelobes similar to flat array provides.

The Suite also allows to design the well-known optimum radiation patterns of flat arrays (like Dolph-Chebyshev, etc.) but for complicated arrays (non-flat, non-equidistant, or consisting of non-isotropic elements). The example is demonstrated in Fig. 6-6.

For some other methods developed in IZMIRAN and included in **MassMIMO Antenna Design Suite** (interelement distance and element positions optimizing, etc.) refer to the paper *Sergeev I.Yu. Two Methods to Decrease Sidelobes for Convex Antenna Arrays // Proceedings of The 21-th International Conference DSPA-2018, V. 1, P. 255-260, Moscow, 2018.*

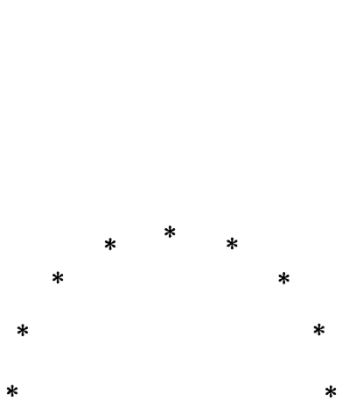


Fig. 6-4. Array configuration

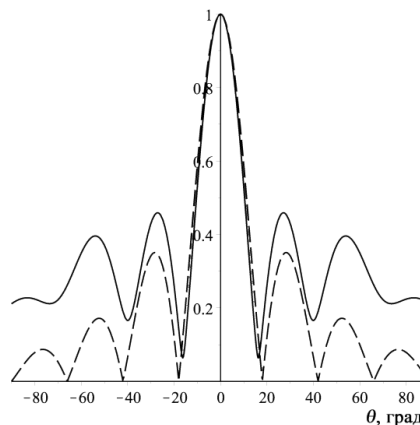


Fig. 6-5.

Solid line – radiation pattern synthesized by the conventional method of co-phased summation in the wanted direction.

Dash line – radiation pattern synthesized by **MassMIMO Antenna Design Suite**.

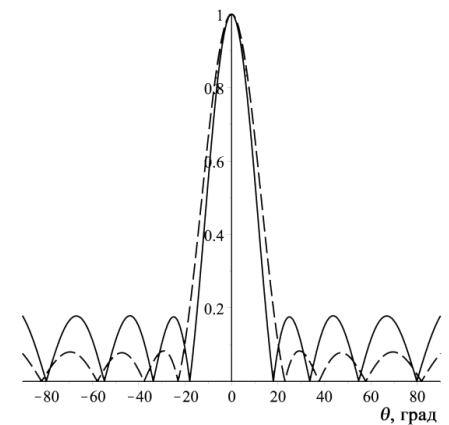


Fig. 6-6. An example of the Dolph-Chebyshev-like optimal radiation pattern but designed for non-flat array shown in Fig. 6-4.

Solid and dash lines are radiation patterns with different sidelobe level.

An example and detailed discussion of a base station cylindrical antenna array designed by **MassMIMO Antenna Design Suite** is presented in the paper *Sergeev I.Yu. Using Multi-Antenna Systems to Form Subcells with the Ability to Dynamically Redistribute the Frequency Resources // Proceedings of The 21-th International Conference DSPA-2018, V. 1, P. 358-362, Moscow, 2018.*