WIPL-D Pro: What is New in v19?

New features/improvements introduced in v19 are:

1. **Scenario Project:**
   a. **Assembly of WIPL-D projects (components), merged into single WIPL-D project (scenario), by using a set of Manipulations commands**
   b. **Components and their copies can be turned on/off with one click**
   c. **Components can be easily deleted or replaced by another WIPL-D project**
   d. **A component can be modified separately, and changes included into scenario with one click**

2. **Voxel Editor:**
   a. **Enables usage of various Voxel formats (Zubal, Mtype-Pvalue, NIFTI-1)**
   b. **Creates human phantoms (breast, head, torso) in native WIPL-D formats**
   c. **Two ways of creation and simplification of phantom: homogenization and decimation**

3. **General Integral Equation Solver:**
   a. **Ability to handle arbitrary Green function through Green Function Calculator (GFC)**
   b. **Half-Space GFC – 3D EM modeling of antennas above real ground**
   c. **PEC/PMC GFC – Alternative way of taking basic symmetry planes into account**

4. **Medical Microwave Imaging (MMWI) Algorithms:**
   a. **Enable detection of tumor/stroke position, shape, and size in simulated MMWI scenario.**
   b. **Two different methods: TSVD and LSM**

5. **Periodic Boundary Condition:**
   a. **Now includes antenna operation mode**
   b. **Junctions are supported in PBC**
   c. **Refined accuracy for cells up to 10λx10λx10λ**
   d. **Simulation accelerated up to 10 times**

6. **Domain Decomposition Solver:**
   a. **Limits: extended to 12 million unknowns**
   b. **Accuracy: increased up to 10 times**
   c. **Simulation time: reduced up to 3 times**

7. **Units:**
   a. **Model dimensions preserved after changing units for structures defined by symbols**
   b. **Enabled import of projects using different set of units**

8. **New features and improvements in WIPL-D Graph Viewer:**
   a. **Plotting the results of mathematical expression**
   b. **Automatic calculation of radiation characteristics such as 3dB beamwidth, 1st side lobe level, F/B ratio, etc.**
   c. **Plotting a predefined mask to visualize the limits of the targeted response**
   d. **Plotting the YZS parameters as a function of port**
   e. **Advanced grid settings including minor grids and adjustable color, style and width of the grid lines**
   f. **Other options: show/hide layers, fitting with normalization, phase unwrapping**

9. **Preview:**
   a. **Show all (hidden entities)**
   b. **Cascade view (multiple open projects)**
   c. **Selection of plates is accelerated for an order of magnitude**
   d. **Multiple selection of virtual plates is enabled together with real plates**

10. **Modeling of large and complex structures:**
    a. **Deleting nodes is accelerated for an order of magnitude**
    b. **Increased maximum number of domains: 4096 different materials applicable in single project**
    c. **Creating/deleting entities in Local Settings, Distributed Loadings and Manipulations is accelerated for an order of magnitude**

11. **Other Features/Improvements:**
    a. **Increased maximum number of Junction nodes (expandable junction table)**
    b. **Increased maximum number of characters in symbol names**
    c. **Group of objects: enabled usage of symbols**
    d. **Enabled usage of tab key in Node/Plate tables**

1. Scenario Project

In WIPL-D Pro environment, scenario represents a complex project that enables the smart merging of multiple IWP designs into one coherent superstructure. Scenario projects share the GUI (graphical user interface) mechanism with standard IWP projects but are enhanced with a simple scripting engine. They enable the assignment of unique global project settings over the entire range of the partial projects involved.

a) Assembly of WIPL-D projects (components), merged into single WIPL-D project (scenario), by using a set of Manipulations commands

Among the other things, the scripting tool performs rotation and translation manipulations over the partial IWP projects. It allows copying those projects and positioning of each copy. This way, creating different complex structures is greatly simplified. For example, to create a realistic representation of medical imaging setup, a scenario project can be utilized to position the blood stroke within the brain region of the head model and to establish the antenna system distributed around the surface of that head, as shown in Fig. 1.
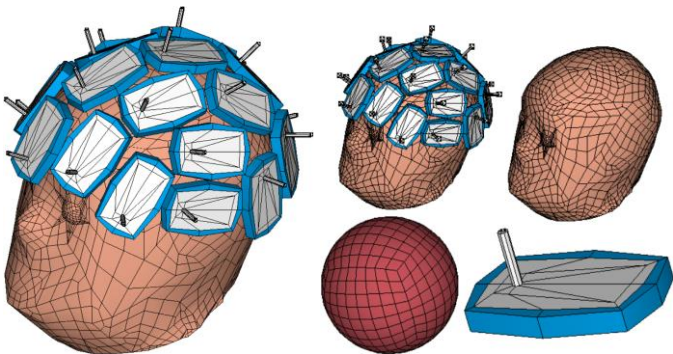

Fig. 1. Complete scenario project (left), and a set of partial projects introduced to the scenario (right): phantom, stroke, single antenna element.

b) Components and their copies can be turned on/off with one click

By simply selecting, and thereafter discarding superfluous antenna elements in the scenario table, it is possible to reduce the size of the antenna array. Restoring back the discarded elements is straightforward. In this way, we obtained two reduced settings of antenna array with the phantom, as shown in Fig. 2.
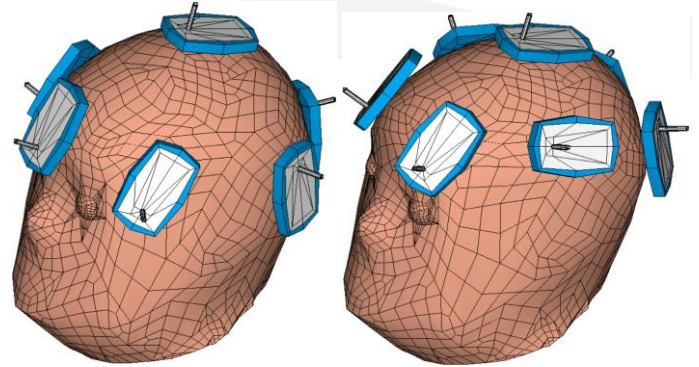

Fig. 2. Different antennas can be easily removed from the antenna array distributed around the head.

c) Components can be easily deleted or replaced by another WIPL-D project

Apart from the fact that it is possible to add new elements to the scenario, it is also possible to replace the existing components of the scenario. E.g., a new antenna project could be inserted in the place of the existing one inside the medical imaging setup. All the settings defined over the scenario would be retained, including the antenna arrangements. The only difference is that the original antenna elements are replaced with new ones. The new elements take the same positions and orientations as the original, as shown in Fig. 3.
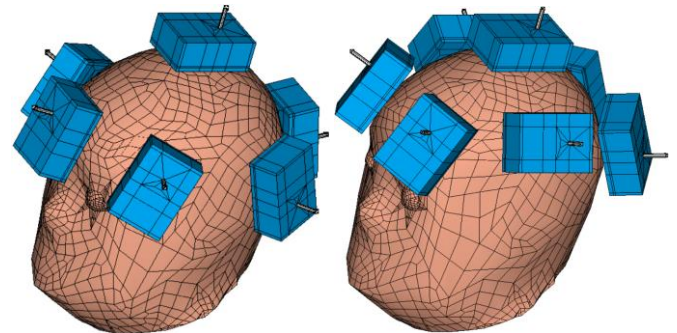

Fig. 3. The distribution of antenna elements has been retained, but the antenna elements have been changed.

d) A component can be modified separately, and changes included into scenario with one click

Each element of the scenario is easily accessible and editable. Regarding the example of the medical setup, it means that after the geometry of an individual antenna is changed and the new geometry is saved, the change propagates to each element of the antenna array and each element changes accordingly. This can be viewed in a broader scope: each modification of an individual project reflects automatically all the copies and manipulations applied to that project inside the scenario, as shown in Fig. 4.
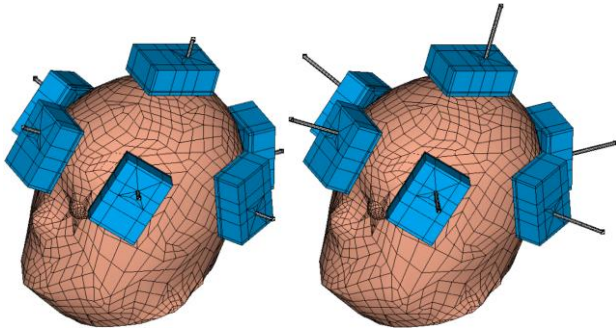
Fig. 4. Increasing the length of the coaxial feed is passed through all elements of the antenna array.

2. Voxel Editor

The voxel file represents dispersive dielectric properties data of a part of the human body, obtained from the MRI (Magnetic Resonance Imaging) or CT (Computed Tomography x-ray) scans. The scan outputs the grid of points (based on specific resolution), distributed in three-dimensional volume that covers the scanned organ or a body part. The output file may contain hundreds of thousands and up to millions of voxels. Due to the exceedingly high complexity, WIPL-D developed procedures for transforming the medical data into electromagnetic models that could be simulated in a reasonable amount of time and provide valuable information for overall phantom analysis.

a) Enables usage of various Voxel formats (Zubal, Mtype-Pvalue, NIFTI-1)

Voxel files are stored in many different formats. WIPL-D Pro supports most common ones. Supported phantom types include Mtype-Pvalue, Zubal and NIFTI-1.

b) Two ways of creation and simplification of phantom: homogenization and decimation

There are two procedures developed by WIPL-D that can be performed on voxel files to provide models suitable for electromagnetic simulations: homogenization and decimation.

The homogenization tool involves grouping adjacent voxels into larger cubic volumes with subsequent averaging of domain features based on initial values. This step significantly reduces the complexity of the model. However, to further simplify the structure, it is necessary to merge adjacent cubic volumes if they have similar values for dielectric properties and make a suitable averaging of the properties for the volume resulting from the merging.

Decimation option merges voxels of the same or similar domain characteristics into connected volumes. These volumes are then redefined using surface shells that precisely define the initial geometry, while significantly reducing the number of elements in the structure. Described shells are first defined in form of triangular geometry that is later transformed into quadrilaterals, as required by the WIPL-D numerical engine.

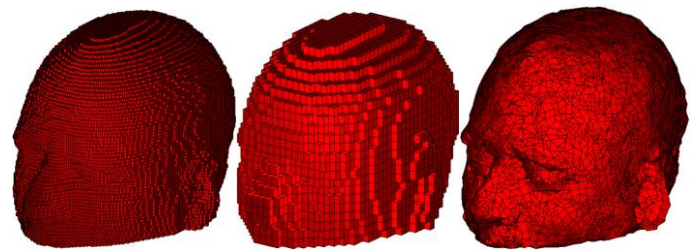These two ways are demonstrated in Fig. 5, starting from initial voxel Zubal phantom.

Fig. 5. Two techniques for simplification of a human head phantom: initial (left), averaged (midle), decimated (left).

c) Creates human phantoms (breast, head, torso) in native WIPL-D formats

With the help of voxel adjusting tools described, it is possible to obtain highly accurate human phantoms, either of complete body or of relevant parts, suitable for numerically efficient WIPL-D simulations, as shown in Fig. 6.
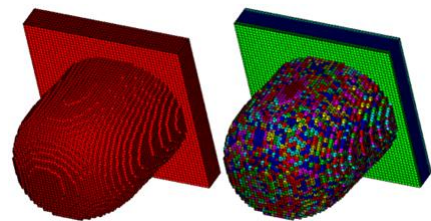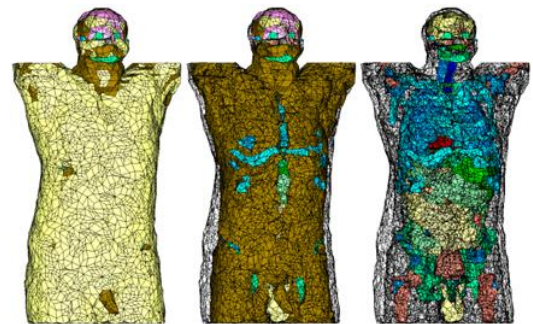

Fig. 6. Torso and breast phantoms created using voxel editor procedures.

3. General Integral Equation Solver

For many years until now, the WIPL-D Pro 3D EM solver was based solely on the higher order Method of Moments

(MoM) applied to Surface Integral Equations (SIEs), which rely on the free-space Green functions (GFs) for arbitrary homogenous, linear and isotropic materials.

a)   Ability to handle arbitrary Green function through Green Function Calculator (GFC)

Recently, we have developed a general form of the method that can use an arbitrary GF added to the free-space one. A specific GF can be included in the solver via the Green Function Calculator (GFC).

The new version (v19) offers three new types of GF, which are included in the solver via internally added GFCs. In the future we plan to add internally some new GFs, but also to enable users to specify their GFs via external GFCs.

All current types of GF consider the influence of specific symmetry planes onto the total field above the symmetry plane. Hence, the GF type is set in the Symmetry dialog box, by choosing one of the options in the Green Function combo box, as shown in Fig. 7.
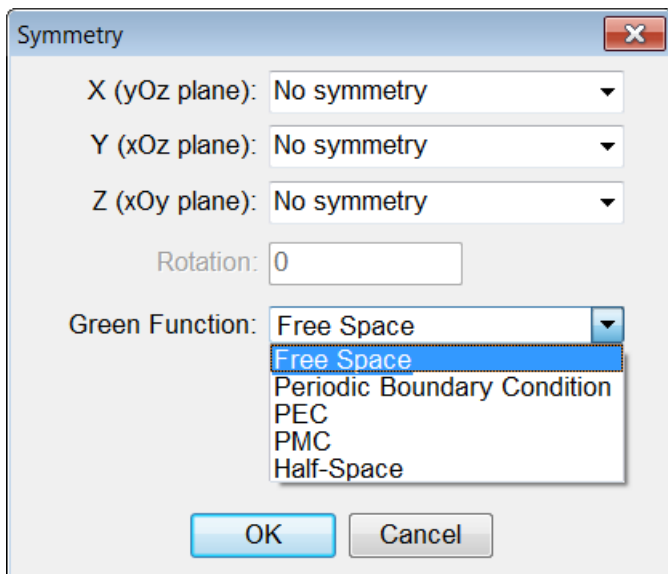

Fig. 7. Symmetry dialog box. Green Function combo box.

In addition to the default "Free Space" option, and previously developed "Periodic Boundary Condition" option, there are three new options: "PEC", "PMC", and "Half-Space".

The effectiveness of these three options will be demonstrated in the example of composite wire-to-plate metallic and dielectric structure, as shown in Fig. 8.
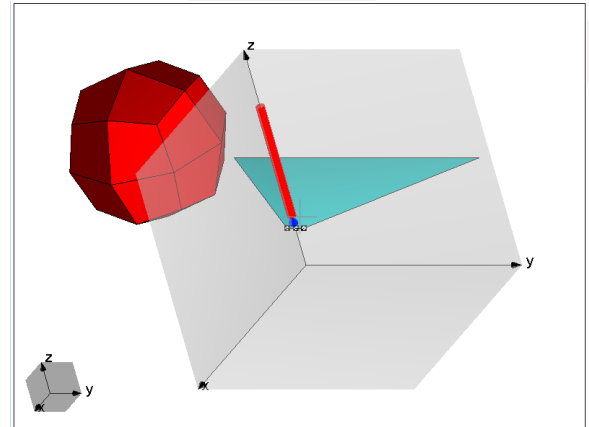

Fig. 8. Composite structure: Wire, fed by point generator, in junction with metallic plate, near dielectric sphere.

The structure is simulated stand alone and by using PEC, PMC, and Half-Space Green Function. The results are compared with those obtained by using standard PEC and PMC symmetry options (see Fig. 9), and by using ground clump to emulate the real ground (see Fig. 10).
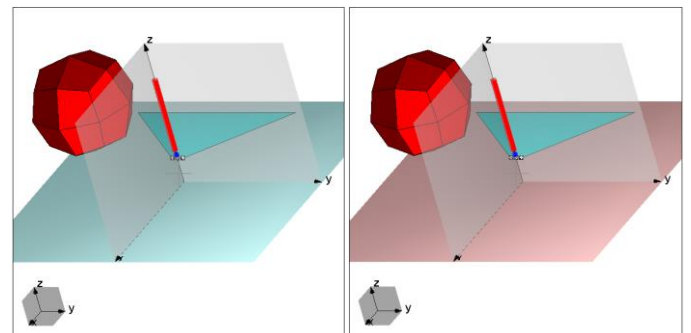

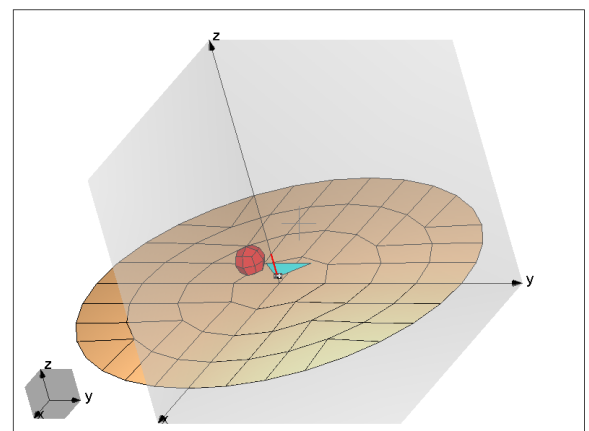Fig. 9. Composite structure above: PEC (left) and PMC(right).

Fig. 10. Composite structure above the ground clump, which emulate the presence of the real ground.

b)   PEC/PMC GFC – Alternative way of taking basic symmetry planes into account

Standard PEC/PMC option (Green Function: Free-Space) is realized by creation of images below the PEC/PMC

plane, which can be inspected in the Show window opened from the Output menu. The new PEC/PMC option is realized via Green Function, thus avoiding creation of images. Both options give the same results, as demonstrated by Fig. 11.
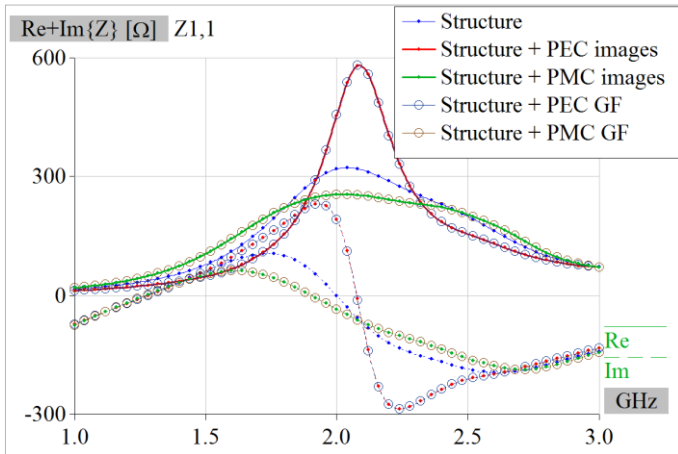

Fig. 11. Impedance versus frequency for composite structures above various types of symmetry planes.

Main purpose of the new PEC/PMC option is to demonstrate effectiveness of the general form of the integral equation solver. It also can be used to cross-check the results of the standard PEC/PMC option.

c) Half-Space GFC 3D EM modeling of antennas above real ground

Previous version (v18) enables simulation of composite structures above the real ground by using the finite ground clump, as shown in Fig. 10. To obtain accurate results by using such model it is necessary to properly set the size of the ground clump. The EM modeling of ground clump usually requires much more unknowns than the composite structure itself.

In the new version (v19) the real ground is considered via the Green Function. Thus, usage of ground clump is avoided, and resources needed for simulation significantly reduced.

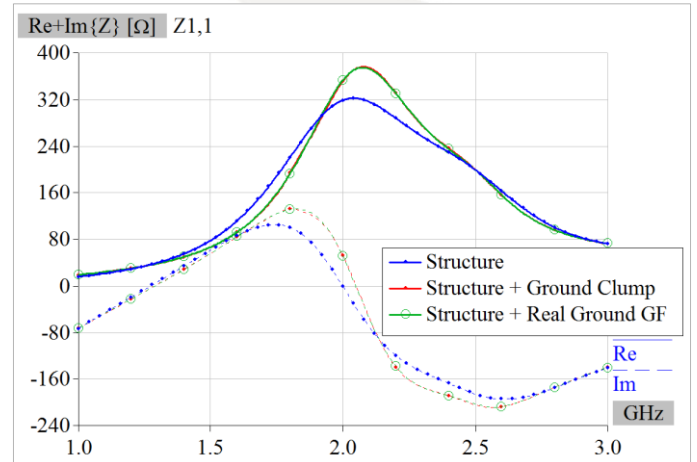These methods give practically the same results, as shown in Fig. 12.

Fig. 12. Impedance versus frequency for composite structure above the real ground.

4. Medical Microwave Imaging (MMWI) Algorithms

Microwave imaging (MWI) is a discipline that allows the detection and evaluation of visually inaccessible objects using electromagnetic (EM) waves in microwave frequency range (300 MHz - 300 GHz). Two frequently used, fast, and reliable qualitative techniques, Truncated Singular Value Decomposition (TSVD) and Linear Sampling Method (LSM), are incorporated into WIPL-D Pro simulation environment. They can be used to determine the shape and the position of the examined object.

MWI is applied in numerous areas including medical diagnostics. Utilization of MWI techniques, for example, enables the detection of tumor/stroke position, shape, and size in simulated MMWI scenarios. Both TSVD and LMS enable such detection and require data obtained from two simulations. Simulations should be performed on the reference model (S-parameters and near filed) and the model with target (S-parameters). The MWI results are displayed in the form of pixelated image, where pixels are normalized to unity.

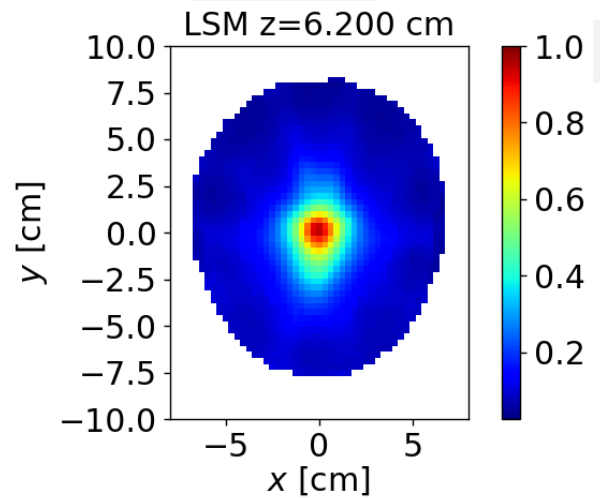### a) Truncated Singular Value Decomposition (TSVD)

Within the introduced MWI feature, when TSVD algorithm is applied, together with the required input of simulation results, it is possible to adjust the truncation coefficient, thus ensuring good quality output.

Typical results are shown in Fig. 13.

TSVD z=6.200 cm

LSM z=6.200 cm
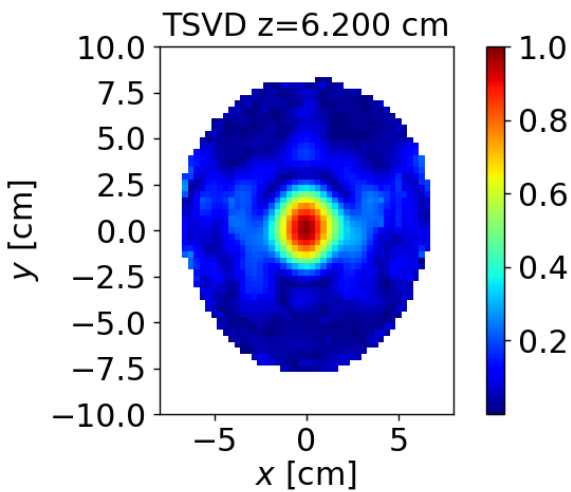
Fig. 14. The result obtained using the LSM algorithm.

Typical results are shown in Fig. 14.

5. Periodic Boundary Condition

a) Now includes antenna operation mode

The new version (v19) enables usage of PBC also for antenna operation mode. The current distribution, near field and far field quantities of an antenna in infinite 2D periodic array should be equal to those of central element of M x M finite array, when M tends to infinity.

Let us consider finite 2D array of dipole antennas, where M=2N+1, and N goes from 1 to 25, as shown in Fig. 15 for N=1 and N=2. Fig. 16 shows that input impedance of the central element in the finite array approaches to the impedance of the element in the infinite array, by increasing N.
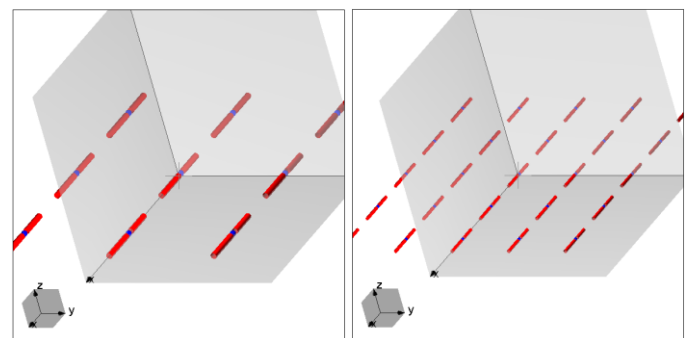

TSVD z=4.600 cm | TSVD z=5.000 cm | TSVD z=5.400 cm
TSVD z=5.800 cm | TSVD z=6.200 cm | TSVD z=6.600 cm
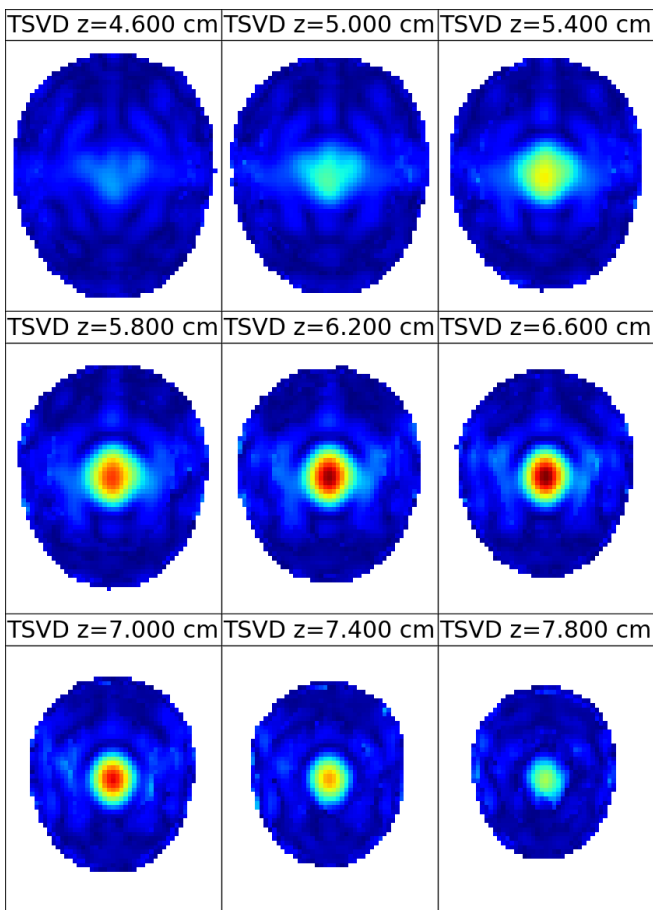TSVD z=7.000 cm | TSVD z=7.400 cm | TSVD z=7.800 cm

Fig. 13. The results obtained using the TSVD algorithm.

b) Linear Sampling Method (LSM)

Regarding the LSM technique, within the new feature it is necessary to upload the results of two simulations. Also, it is possible to modify the value of the regularization parameter to achieve better quality results.
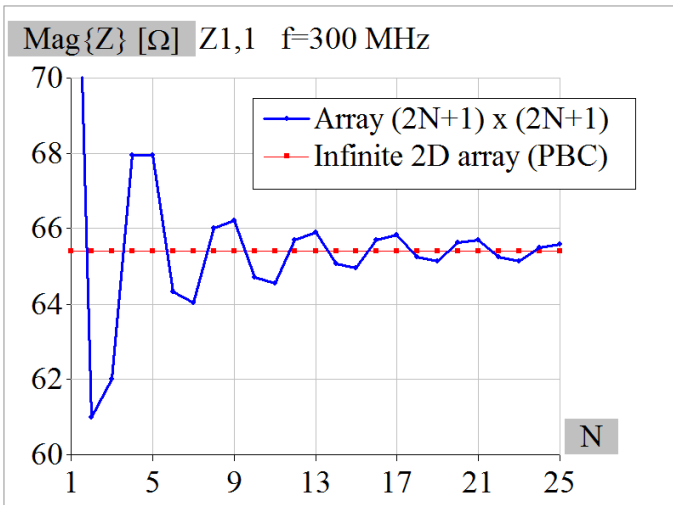

Fig. 15. Sketch of array of (2N+1) x (2N+1) dipole antennas: N=1 (left) and N=2 (right)

Fig. 16. Impedance of central element in array of (2N+1) x (2N+1) dipole antennas, compared to impedance of the central element in the infinite 2D array

b) Junctions are supported in PBC

From this version, junctions defined in PBC projects are considered during the simulations.

c) Refined accuracy for cells up to 10λx10λx10λ

Extensive use of the previous version (v18) indicated that in some cases of larger cells the values of 2D periodic Green Function were not calculated correctly. Algorithms for evaluation of 2D periodic Green functions were refined in a few iterations and heavily tested until high accuracy and reliability of the algorithms were achieved.

d) Simulation accelerated up to 10 times

Evaluation of PBC Green functions is 2-3 orders of magnitude more time consuming than that of free space Green function. To speed up the calculations we have developed a sophisticated interpolation algorithm for initial grid of PBC Green functions calculated inside the periodic cell. Depending on the density of the initial grid, the interpolation results in smaller or larger error, so that for higher accuracy the PBC Green function needs to be calculated directly. The user can choose 6 levels of acceleration. By increasing the level of acceleration, the level of accuracy decreases slightly. Recommended initial value is 6, as shown in Fig. 17, giving acceptable results in practically all cases, but accelerating the calculations for one order of magnitude.
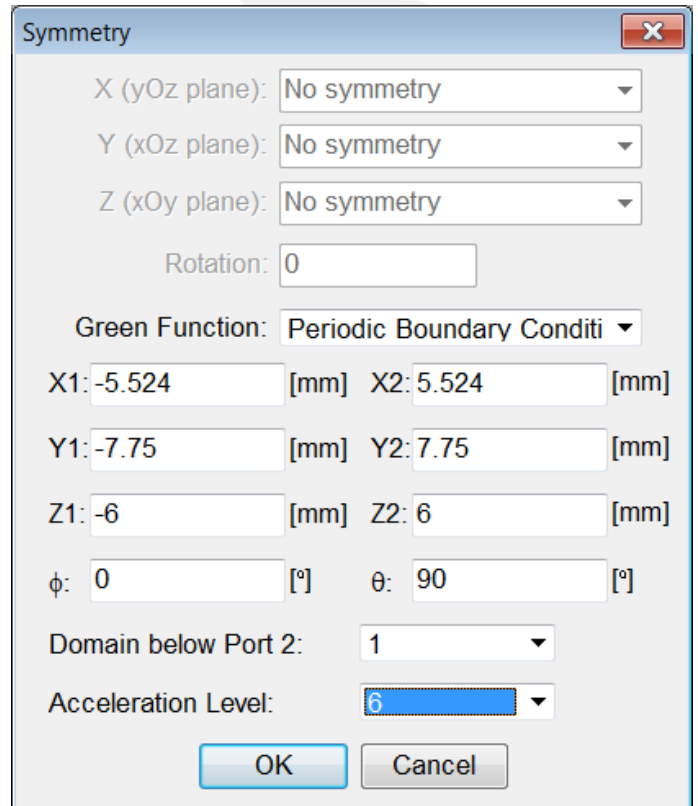

Fig. 17. Symmetry dialog box with Green Function set to Periodic Boundary Condition.

6. Domain Decomposition Solver (DDS)

Detailed description of novelties in DDS are presented in the document: "What is New in DDS?".

7. Units

The Units window has been updated and enhanced to match the capabilities of the equivalent option in the WIPL-D Pro CAD environment. The keep model dimensions checkbox has been introduced and is active by default. When this option is checked, by changing the units, an adequate scaling of the parameters defining the project is performed, keeping the original values (for example 1 m becomes 1000 mm). In case the keep model dimensions option is deactivated, changing the units effectively changes the model parameters. The values that define the physical property are retained while the unit is changed (for example 3 V becomes 3 mV).
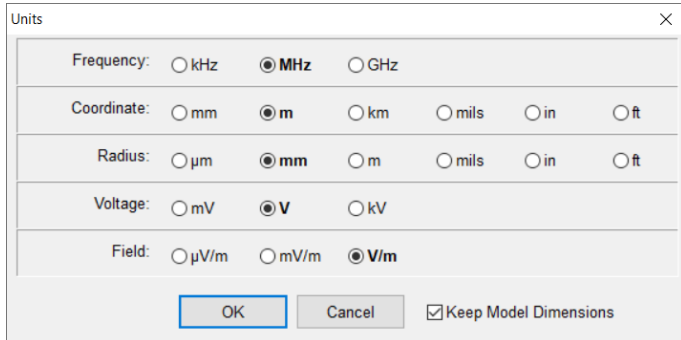
Fig. 18. Units window.

a) Model dimensions preserved after changing units for structures defined by symbols

In the case that keep model dimensions is active, the functionality of the program is improved. From the new version, adequate scaling is also applied to symbolically defined parameters (for example symbol1 m becomes symbol1*1000 mm). This removes any restrictions that would limit unit changes.

b) Enabled import of projects using different set of units

Owing to the changes described under point a), it became possible to scale models while importing them into the main project. Consequently, it is no longer necessary to unify units in the active and imported projects, before the import action.

8. New features and improvements in WIPL-D Graph Viewer

In WIPL-D Graph Viewer, we are continuing to add new enhancements to provide a more user-friendly and intuitive working environment. Each new version of our software brings development of brand new features and improvements of the existing ones, with the ultimate goal to constantly increase the functionality and diversity of the viewer.

a) Plotting the results of mathematical expression

In the current release of the software, we are expanding the choice in our format palette by adding a brand-new format, Math expression. With increased functionality of the viewer, the users can now display a variety of custom defined results. An expression is a predefined function or a combination of predefined functions and mathematical operations available in our Symbolic mechanism. Besides typing the mathematical expression, the users can specify both axes and cuts for their plot, all in the same place.

By introducing Math expression, we are tremendously increasing possibilities for representing results. The first example demonstrates using Math expression to calculate the mismatch efficiency versus frequency of an arbitrary antenna. The corresponding expression is: 100*($FFRealizedGain(1)/$FFGain(1)).
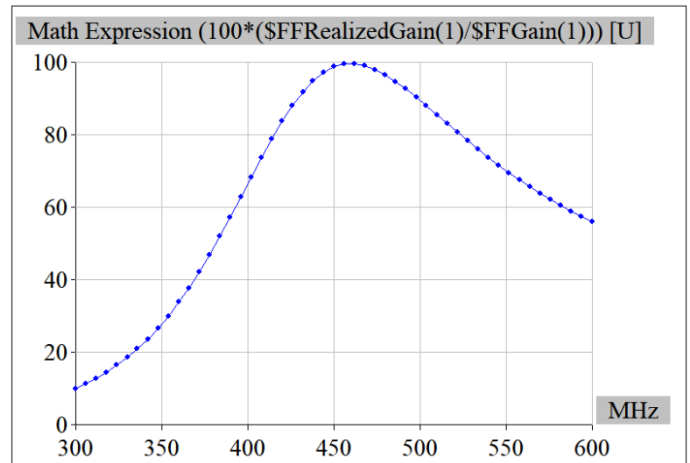

Fig. 19. Mismatch radiation efficienty versus frequency using Math expression.

In the previous versions of our software, only comparison of 3D plots was available. The second example demonstrates improvement in that field, showing the possibility to plot the difference between two 3D plots using Math expression. The corresponding expression is: $Trace(1)-$Trace(2).
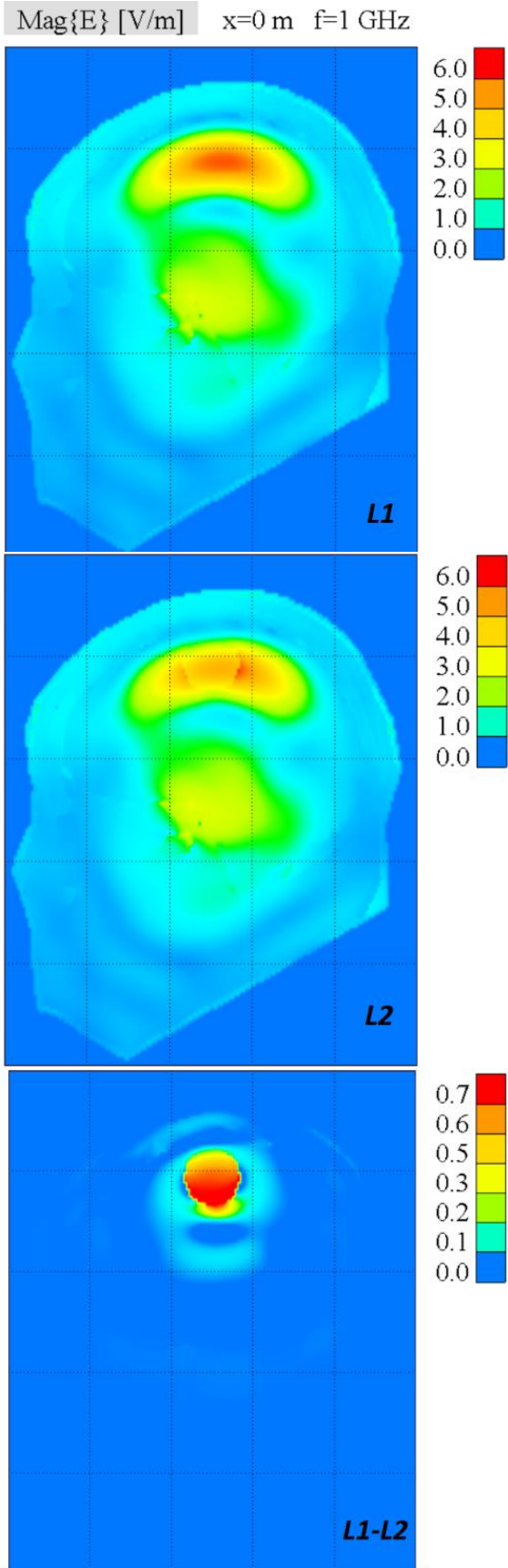
Mag{E} [V/m]   x=0 m   f=1 GHz

Fig. 20. Diference between two layers using Math expression.

b)   Automatic calculation of radiation characteristics

Additional useful information about radiation pattern is available now:

- 3dB Beamwidth (HPBW)
- Null to Null Beamwidth (NNBW)
- First Null Beamwidth (FNBW)
- Left/ Right Side Lobe (LSL/RLS)
- Left/Right Null (LN/RN)
- Front to Back (F/B)
- Front to Side Lobe (F/S)
- Peak Value (PV)

Furthermore, the users can custom define desirable Null criteria, as well as plot an additional beamwidth. Depending on users' preferences, a table with additional information is presented beside the every graph, allowing systematic overview of selected features. Supported even in the Overlay mode, Radiation Characteristics follow important parameters of all displayed graphs. This option is available for 2D graphs (polar and cartesian).
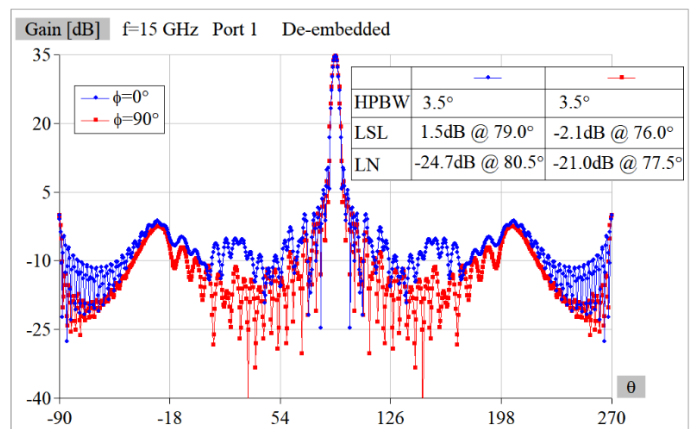

Gain [dB]   f=15 GHz   Port 1   De-embedded

	φ=0°	φ=90°
HPBW	3.5°	3.5°
LSL	1.5dB @ 79.0°	-2.1dB @ 76.0°
LN	-24.7dB @ 80.5°	-21.0dB @ 77.5°

Fig. 21. Radiation characteristics (HPBW, LSL, LN) of parabolic reflector antenna.

c)   Plotting a predefined mask to visualize the limits of the targeted response

Starting from this version, it is possible to plot arbitrary mask in the viewer to visualize the limits of the targeted response. The mask assists in quick analysis of achieved results, providing the users with a more intuitive way to keep track with their work. The users can define mask in two ways: either by filling in the corresponding table in the mask dialog box or by importing mask file with desirable values. An example of a mask defined for LP filter is shown in the figure below.
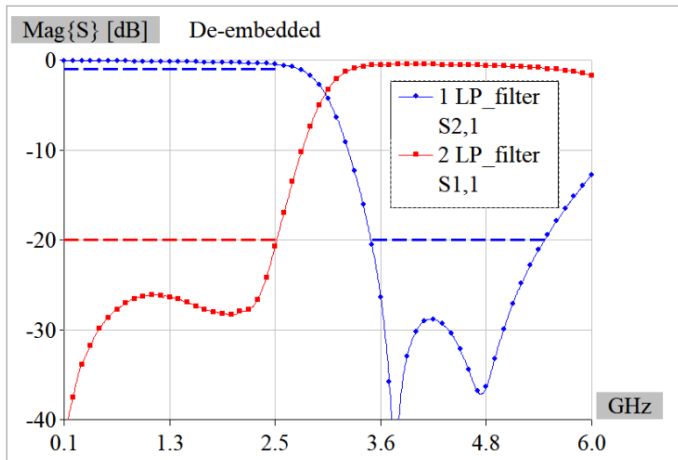
Fig. 22. Mask defined for LP filter.

d) Plotting the YZS parameters as a function of port

In this release we are expanding the list of available axes for plotting by adding new variables. The YZS parameters can now be displayed as a function of port by choosing row(i) or column(j) elements in the circuit matrix. This option is available for one generator at time operation mode, if the number of ports is greater than one.

As an example, we are presenting S parameters of a 21 ports circuit, displayed as a function of j elements in the circuit matrix. Setting the x-axis to column(j) allows the users to choose freely desired row(i) and frequency. The row(i) and column(j) take values between 1 and total number of ports. By introducing this option, monitoring the influence each port has on the YZS results is more intuitive and efficient.
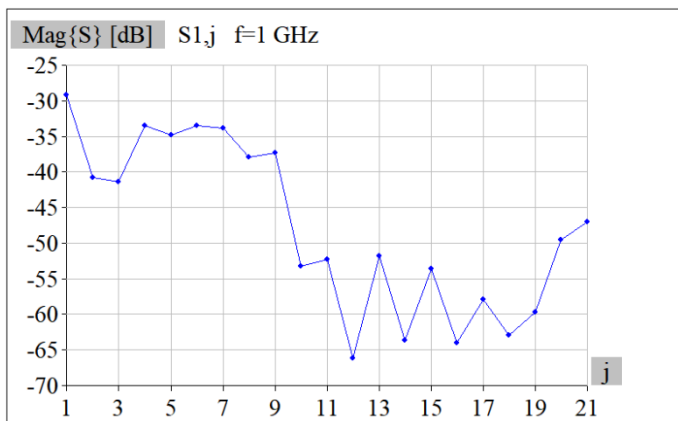

Fig. 23. S parameters as a function of port.

e) Advanced grid settings including minor grids and adjustable color, style and width of the grid lines

This release brings an improvement to the grid option to make data in a graph easier to read. The users can now custom define horizontal and vertical grid on the

presented graph, both major and minor type. A variety of choices lay ahead when customizing grids. The users can independently choose line style and width, as well as the color, of their grids. Showing the grids is also optional, providing the users full freedom in customizing their graph.

Fig. 24. shows both horizontal and vertical major and minor grids. Line style for major grids is solid, while line style for minor grids is dashed. The color of the grid lines is grey.
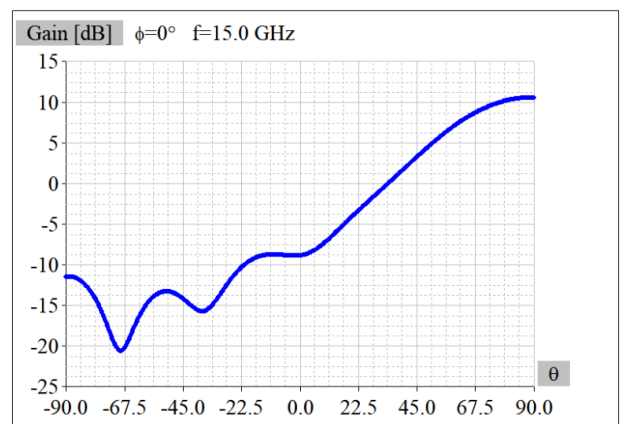

Fig. 24. Customization of major and minor grid.

f) Other options: show/hide layers, fitting with normalization, phase unwrapping

Overlaying numerous graphs is neater than ever. The users now have a quick and easy way to inspect multiple layers without removing them. Show/Hide layer is the new feature allowing the users to show or hide an arbitrary number of layers.

Fitting with normalization is a significant improvement in interpolation of Sij (i!=j) when the distance between antennas is much greater than the wavelength. This option reduces the number of frequency points up to 3 times without any impact on the accuracy of results.

In the previous version of our software the phase is wrapped in the range from -180° to 180° by default. From this version, we are introducing Phase Wrapping option, allowing the users to choose whether the phase is wrapped or unwrapped. The appearance of the phase is now entirely based on the users' preferences.

9. Preview

With the increase in computing power, the demand placed on the software also rises. There is a clear surge in the size and complexity of the models placed in front of the software. Along with improving the calculation engine

and increasing the complexity of the model, it is necessary to improve and speed up the modeler.

a) Show all (hidden entities)

To make hidden parts of the structure visible again, use the newly introduced Show all feature. Unlike the Home button, this option does not affect the position of the structure on the Preview window.

b) Cascade view (multiple open projects)

Navigating through multiple projects simultaneously can be achieved through the Cascade option. This feature now closely matches the WIPL-D Pro CAD equivalent. It is possible to open several projects on the screen and select the active one using the Activate button. All other windows remain locked in the state they were left in, until they are activated again.

c) Selection of plates is accelerated for an order of magnitude

This is especially noticeable in projects with an exceedingly large number of plates. The responsiveness of the Preview window has been significantly improved.

d) Multiple selection of virtual plates is enabled together with real plates

Virtual plates belong to defined objects and are not written into the Plates table. Previously, it was impossible to mark more such plates without automatically selecting complete objects. Multiple virtual plates selection is now enabled. It is completely equal to the regular plates' selection. This includes both Window selection and selection using the Ctrl button.

10. Modeling of large and complex structures

To better accommodate ever increasing complexity of the models occurring in modern EM simulation scenarios, certain restrictions have been relaxed and some of the options have been accelerated.

a) Deleting nodes is accelerated for an order of magnitude

Deleting unused nodes is dramatically accelerated.

b) Increased maximum number of domains: 4096 different materials applicable in single project

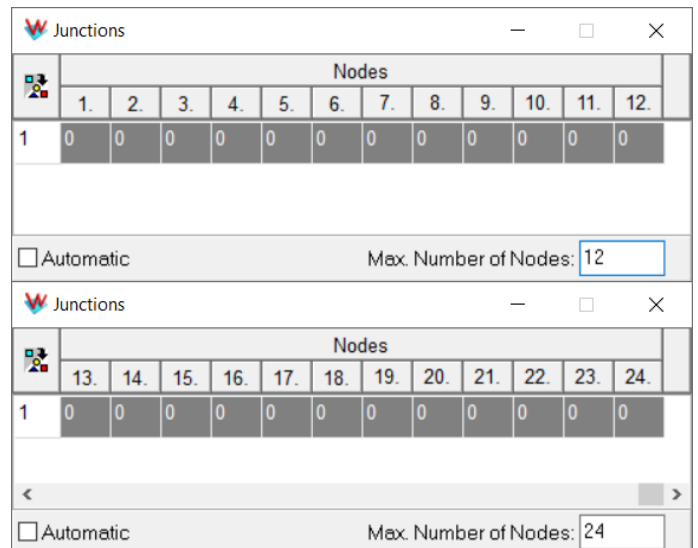The limit for the number of defined domains in a single project has been raised to 4096.

c) Creating/deleting entities in Local Settings, Distributed Loadings and Manipulations is accelerated for an order of magnitude

Setting and changing Local Settings, Distributed Loadings and Manipulations over a large number of entities (wires, plates, objects) is noticeably accelerated. This is especially appreciable on extremely large projects.

11. Other Features/Improvements

a) Increased maximum number of Junction nodes (expandable junction table)

The limitation of a maximum of 12 nodes that could be used to define a single junction is removed. In the Junction table, it is now possible to enter the Max. Number of Nodes parameter that will be used in the project to define the junctions. Fig. 25 shows what the initial layout of the table, with 12 nodes, looks like and the expanded layout with the nodes limit raised to 24.

Fig. 25. Junctions table when Max. Number of Nodes is set to 12 (above) and 24 (below).

b) Increased maximum number of characters in symbol names

The limitation of using no more than 8 characters to define symbols has been removed.

c)   Group of objects: enabled usage of symbols

To enable the creation of scalable projects inside a group, it is possible to numerate objects using symbols. Symbols that are used for this purpose must have an integer value. Symbols can be used to define individual objects (or ranges of objects) introduced into a group (for example oA or oN-M), as shown in Fig. 26.
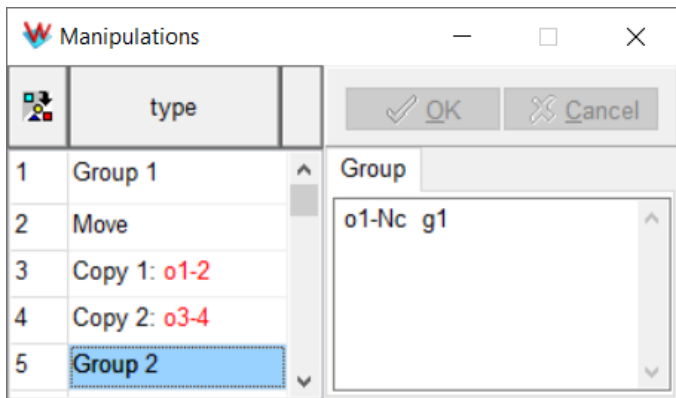

Fig. 26. Group of objects is defined using the symbol Nc=2.

Now, changing the symbol value, for example, changes the dimension of the antenna array. Fig. 29 demonstrates how changing the value of the symbol Nc from 2 to 5 changes the geometry of the project.
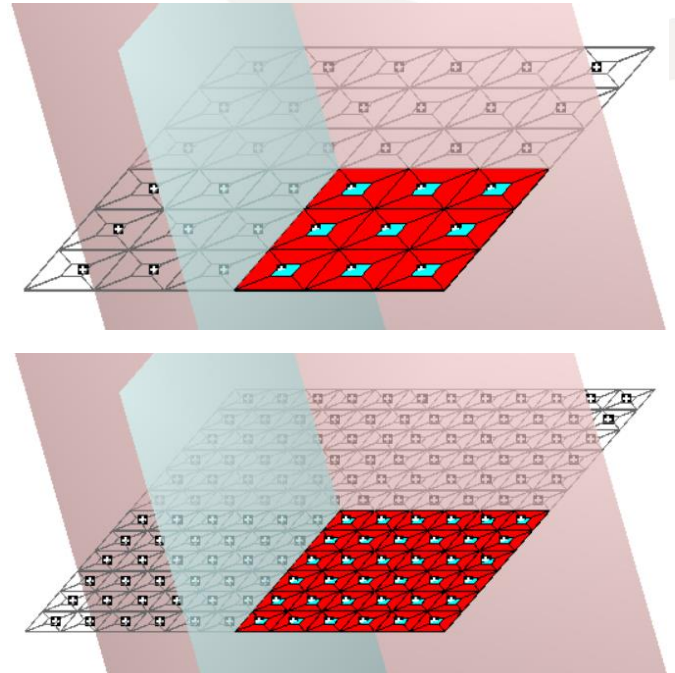

Fig. 27 Antenna array size increases with increasing value of symbol Nc.

d)   Enabled usage of tab key in Node/Plate tables

It is possible to use the Tab button for more efficient keyboard navigation through the Nodes and Plates tables.