ERMES USER GUIDE

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Chapter 1

ERMES user guide

This document is the user manual of ERMES. We explain step-by-step how to run a numerical simulation with this computational tool.

1.1 Description of ERMES

The C++ implementation of the method explained in [2] is called ERMES (*E*lectric *R*egularized *M*axwell *E*quations with *S*ingularities). ERMES has a user-friendly interface based on GiD [1]. GiD is employed for geometrical modeling, meshing and visualization of results. The current version of ERMES is mono-processor and it runs in the operative system Windows XP (64-bits and 32-bits). The graphic interface works with GiD 10 and lower versions.

1.2 Installation

ERMES is a problem type of GiD and, therefore, we only have to *copy&paste* the folder *ERMES 6.0* in the folder *problemtypes* of GiD to install it. ERMES is opened in the upper menu of GiD *Data* → *Problem type* → *ERMES 6.0* → *ERMES* (see fig. 1.1). The ERMES menu bar appears at the left side of GiD after clicking on *ERMES* (see fig. 1.2).

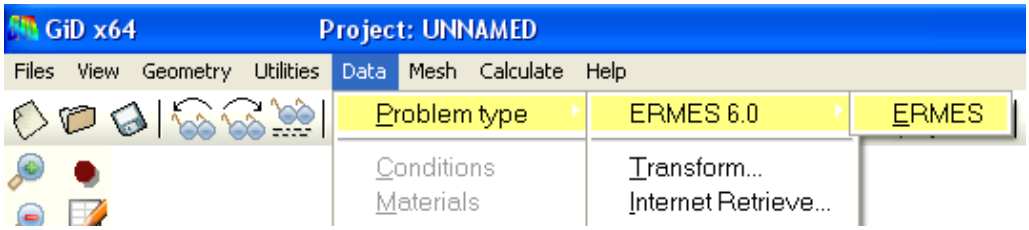

Figure 1.1: ERMES is opened in the upper menu of GiD *Data* → *Problem type* → *ERMES 6.0* → *ERMES*.

1.3 Pre-Process

Before running a simulation with ERMES we need to create a geometry, define materials, apply boundary conditions and set problem parameters. The geometry can be imported or created inside GiD. It is important to remember that ERMES needs two different surfaces, joined by *contact elements*, for modeling the discontinuity of the fields in the surface of separation between two media [2]. The materials, boundary conditions and problem parameters must be defined and assigned from the windows associated to the ERMES menu bar. In the following subsections we describe these windows in detail. Once the problem is set up properly, we only have to mesh the geometry (clicking on the *Generate mesh* button) and, finally, execute ERMES (clicking on the *Calculate* button).

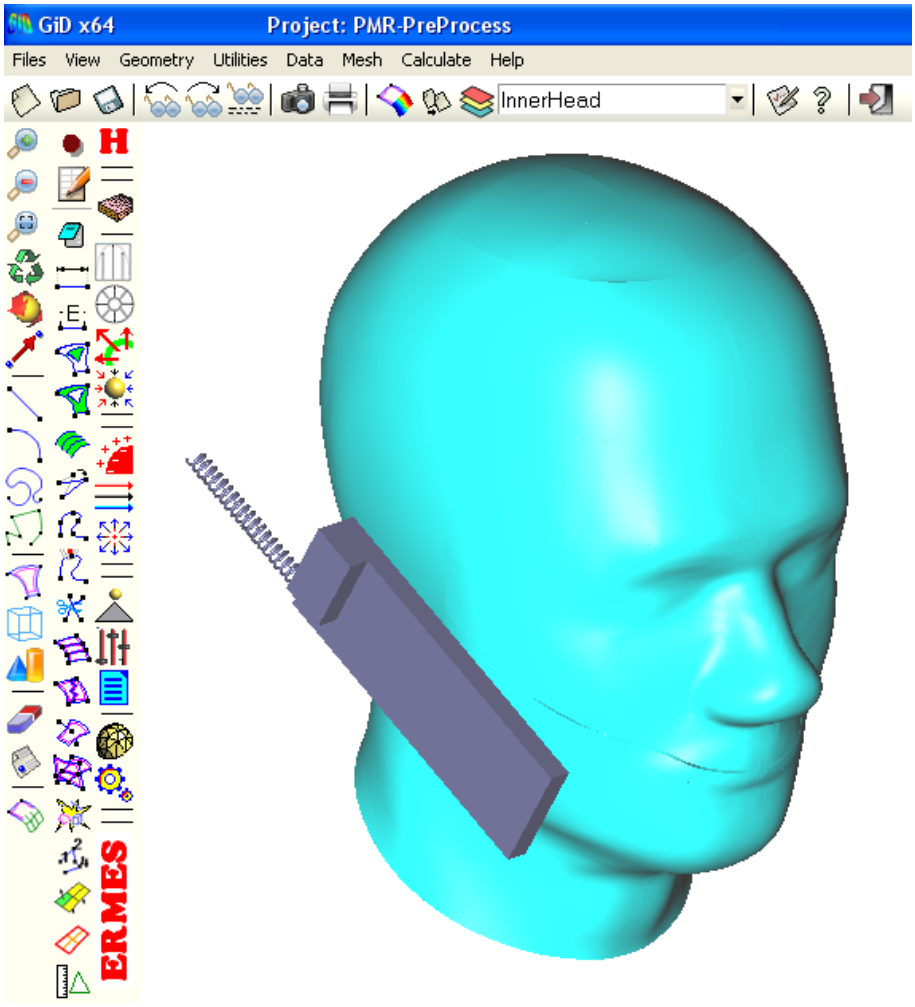

Figure 1.2: ERMES menu bar.

1.3.1 Materials

The window *Materials* (see fig. 1.3) defines materials and assigns it to the volumes of the geometry. The material properties required are:

- *Electrical conductivity (S/m)*: electrical conductivity σ (S/m).
- *Electric permittivity real*: real part of the relative electric permittivity $\epsilon_r^{'}$ $(\epsilon^{'}/\epsilon_0)$.
- *Electric permittivity img*: imaginary part of the relative electric permittivity $\epsilon_r^{''}$ $(\epsilon^{''}/\epsilon_0)$.
- *Magnetic permeability real*: real part of the relative magnetic permeability $\mu_r^{'}$ $(\mu^{'}/\mu_0)$.
- *Magnetic permeability img*: imaginary part of the relative magnetic permeability $\mu_r^{''}$ $(\mu^{''}/\mu_0)$.

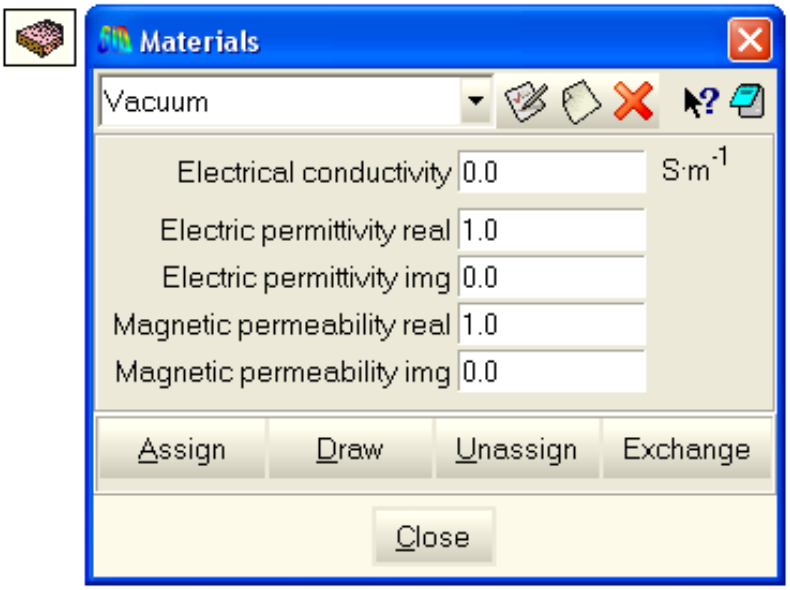

Figure 1.3: *Materials* window.

1.3.2 RWPort TE10

The window *RWPortTE10* (see fig. 1.4) defines the rectangular waveguide ports. The parameters required are:

- *Port Type*: ID number. $PortType = 0$ for an input port. $PortType > 0$ for an output port.
- *00 X*: X coordinate of the lower left corner of the port.
- *00 Y*: Y coordinate of the lower left corner of the port.
- *00 Z*: Z coordinate of the lower left corner of the port.
- *high X*: X coordinate of the upper left corner of the port.
- *high Y*: Y coordinate of the upper left corner of the port.
- *high Z*: Z coordinate of the upper left corner of the port.
- *width X*: X coordinate of the lower right corner of the port.
- *width Y*: Y coordinate of the lower right corner of the port.
- *width Z*: Z coordinate of the lower right corner of the port.

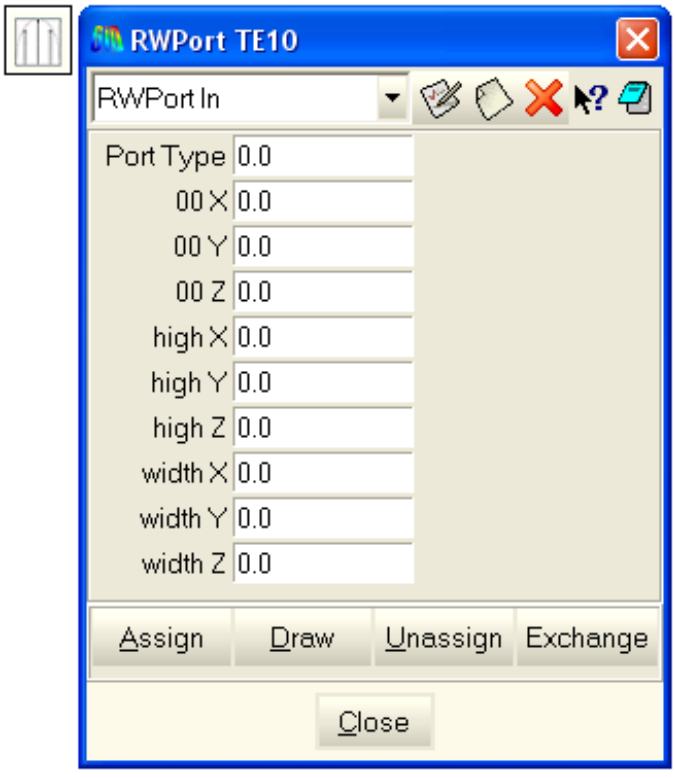

Figure 1.4: *RWPortTE10* window.

1.3.3 CoaxialPort TEM

The window *CoaxialPortTEM* (see fig. 1.5) defines the coaxial waveguide ports. The parameters required are:

- *Port Type*: ID number. $PortType = 0$ for an input port. $PortType > 0$ for an output port.
- *00 X*: X coordinate of the center of the coaxial waveguide port.
- *00 Y*: Y coordinate of the center of the coaxial waveguide port.
- *00 Z*: Z coordinate of the center of the coaxial waveguide port.
- *Inner radius a*: radius of the inner cylinder of the coaxial waveguide.
- *Exterior radius b*: radius of the exterior cylinder of the coaxial waveguide.
- *Electric permittivity*: real part of the relative electric permittivity $\epsilon_r^{'}\,(\epsilon^{'}/\epsilon_0)$ of the medium inside the coaxial waveguide.
- *Magnetic permeability*: real part of the relative magnetic permeability $\mu_r^{'}\,(\mu^{'}/\mu_0)$ of the medium inside the coaxial waveguide.

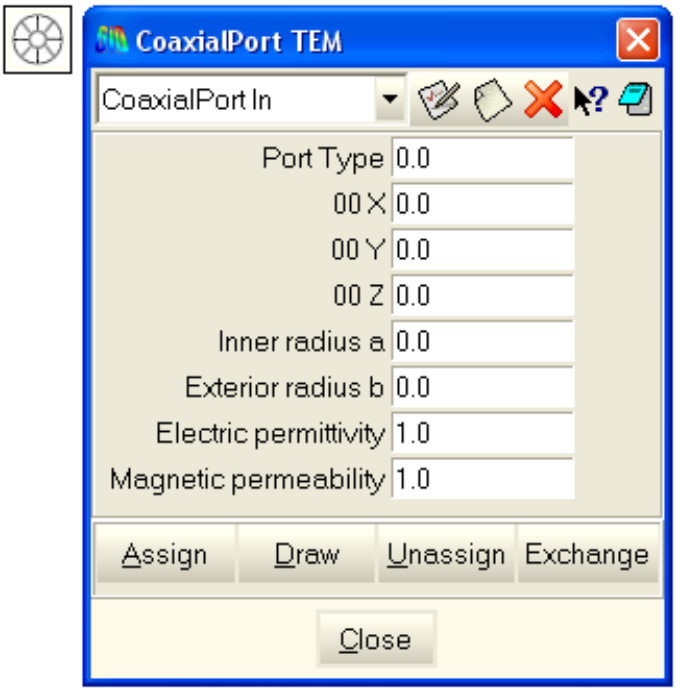

Figure 1.5: *CoaxialPortTEM* window.

1.3.4 Generic Robin Coefficients

The window *Generic Robin Coefficients* (see fig. 1.6) defines the coefficient γ that appears in the boundary condition

$$\hat{\mathbf{n}} \times \nabla \times \mathbf{E} - \gamma \left(\hat{\mathbf{n}} \times \hat{\mathbf{n}} \times \mathbf{E} \right) = 0. \tag{1.1}$$

The parameters required are:

- *Robin coef real*: real part of the coefficient γ.
- *Robin coef img*: imaginary part of the coefficient γ.

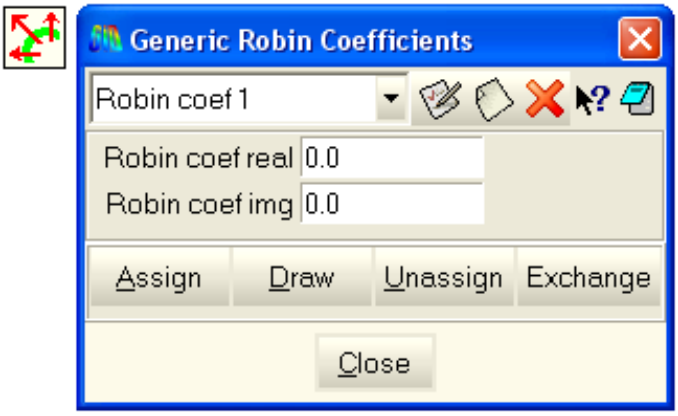

Figure 1.6: *Generic Robin Coefficients* window.

1.3.5 Current Sources Properties

The window *Current Sources Properties* (see fig. 1.7) defines the electric current densities. The parameters required are:

- *Jx (A/m^2)*: modulus of the X component of the electric current density.
- *Phase x (rad)*: phase of the X component of the electric current density.
- *Jy (A/m^2)*: modulus of the Y component of the electric current density.
- *Phase y (rad)*: phase of the Y component of the electric current density.
- *Jz (A/m^2)*: modulus of the Z component of the electric current density.
- *Phase z (rad)*: phase of the Z component of the electric current density.
- *Ja (A/m^2)*: modulus of the angular component of an axis symmetric current density around the Y axis.
- *Phase a (rad)*: phase of the angular component of an axis symmetric current density around the Y axis.

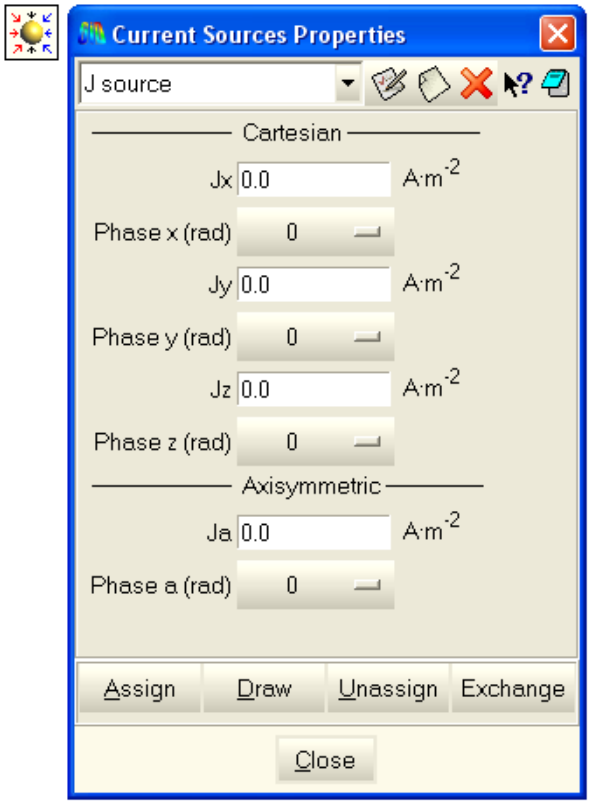

Figure 1.7: *Current Sources Properties* window.

1.3.6 Dirichlet Conditions

The window *Dirichlet Conditions* (see fig. 1.8) assigns the following conditions:

- *Singularity*: number of *Ungaged Layers* (see section 3.5) around to a point or line.
- *Electric Field PEC*: perfect electric conductor boundary condition ($\hat{\mathbf{n}} \times \mathbf{E} = 0$).
- *Electric Field PMC*: perfect magnetic conductor boundary condition ($\hat{\mathbf{n}} \cdot \mathbf{E} = 0$).
- *Electric Field TE Port*: boundary condition $\hat{\mathbf{n}} \cdot \mathbf{E} = 0$ for waveguide ports. It avoids the geometric average of the boundary normals at the intersection of a port surface with a PMC surface.
- *Correct Contact Normals*: makes coherent the definition of the normals at the surfaces of discontinuity between two media (see section 3.4).

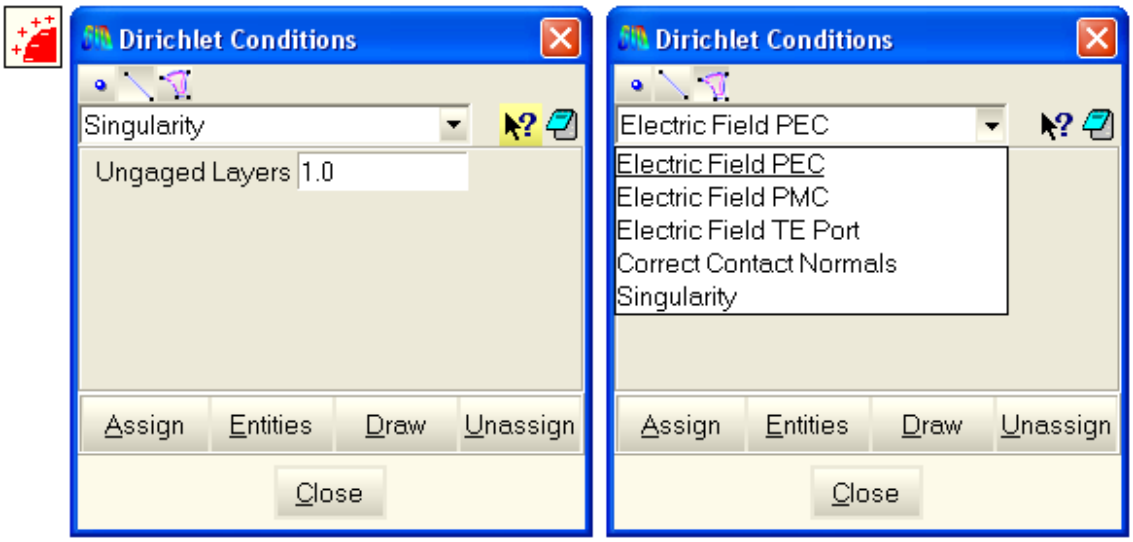

Figure 1.8: *Dirichlet Conditions* window.

1.3.7 Robin Conditions

The window *Robin Conditions* (see fig. 1.9) assigns the boundary condition

$$\hat{\mathbf{n}} \times \nabla \times \mathbf{E} - \gamma \left(\hat{\mathbf{n}} \times \hat{\mathbf{n}} \times \mathbf{E} \right) = \mathbf{U}, \tag{1.2}$$

being the parameters γ and $\mathbf{U}$ the following:

- *RW Port TE10 Conditions*: γ is the propagation constant of the mode TE_{10}.
  If $PortType = 0$ then $\mathbf{U} = -2\,\gamma \left(\hat{\mathbf{n}} \times \hat{\mathbf{n}} \times \mathbf{E}_{10} \right)$.
  If $PortType > 0$ then $\mathbf{U} = 0$.
  The rectangular waveguide ports are defined in the window *RWPortTE10*.
- *Coaxial TEM Conditions*: γ is the propagation constant of the mode TEM.
  If $PortType = 0$ then $\mathbf{U} = -2\,\gamma \left(\hat{\mathbf{n}} \times \hat{\mathbf{n}} \times \mathbf{E}_{\mathrm{TEM}} \right)$.
  If $PortType > 0$ then $\mathbf{U} = 0$.
  The coaxial waveguide ports are defined in the window *CoaxialPortTEM*.
- *Far Field Condition*: $\gamma = i\omega\sqrt{\epsilon_0 \mu_0}$ and $U = 0$.
- *Generic Robin Condition*: γ is defined in the window *Generic Robin Coefficients* and $U = 0$.

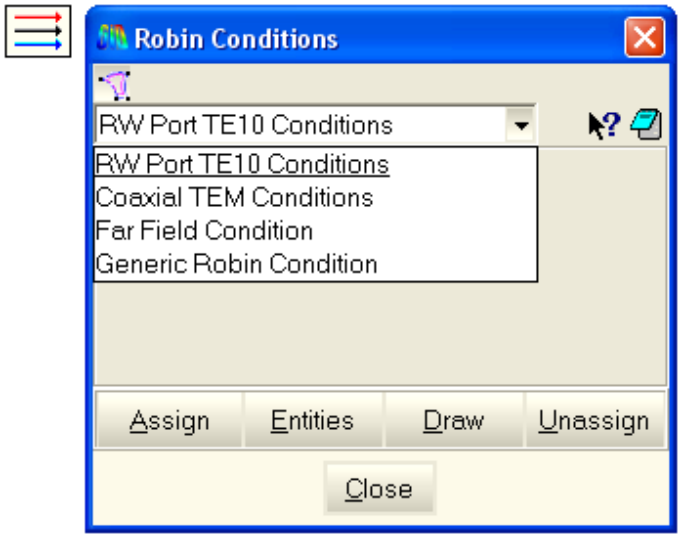

Figure 1.9: *Robin Conditions* window.

1.3.8 Current Sources

The window *Current Sources* (see fig. 1.10) assigns to volumes the electric current densities defined in the window *Current Sources Properties*.

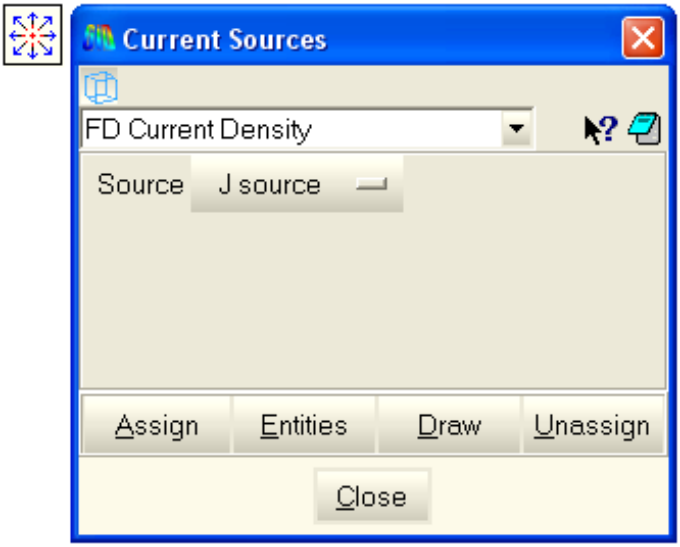

Figure 1.10: *Current Sources* window.

1.3.9 Modes Projection

The window *Modes Projection* (see fig. 1.11) selects the waveguide ports, surfaces and volumes over which the computed fields are integrated:

- *Projection RWTE10*: computes the scattering parameter S_{ij} over the selected rectangular waveguide port.
- *Projection CoaxialTEM*: computes the scattering parameter S_{ij} over the selected coaxial waveguide port.
- *Field Surface Integral*: integrates the fields over the selected surface.
- *Field Volume Integral*: integrates the fields over the selected volume.

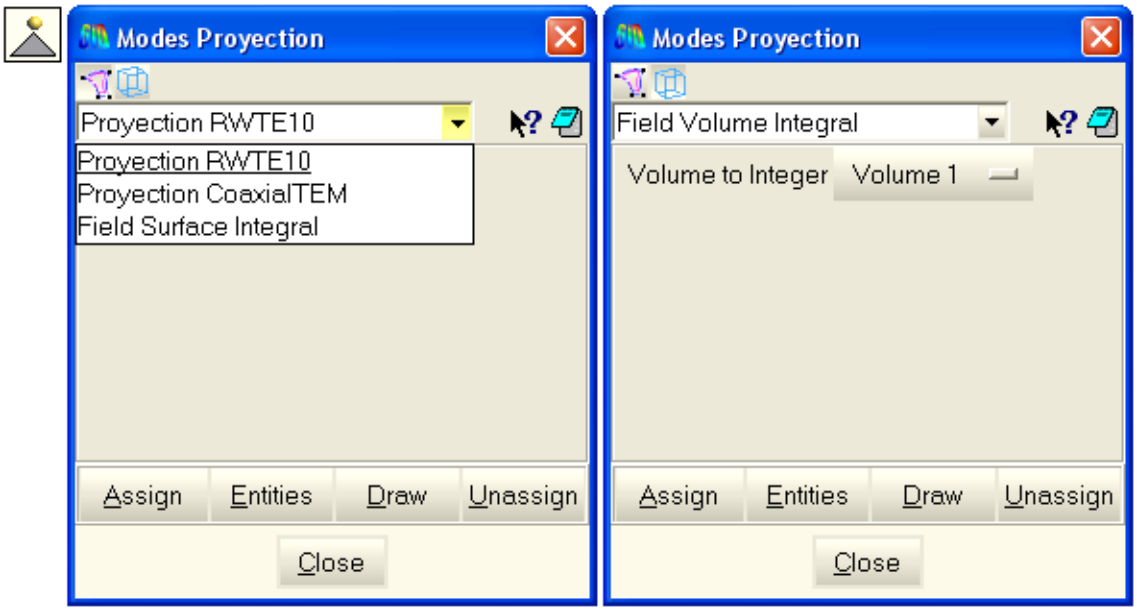

Figure 1.11: *Modes Projection* window.

1.3.10 Solving Parameters

The window *Solving Parameters* (see fig. 1.12) sets the problem parameters. It contains three tabs: *Frequency*, *Solvers* and *Geometric Data*.

The *Frequency* tab sets the parameters:

- *Frequency (Hz)*: problem frequency in Hz. If the checkbox *Frequency sweep* is checked then it is disabled.
- *Frequency sweep*: frequency sweep starting at *Initial freq*, ending at *End freq* and with a step *Step freq*. If the checkbox *Frequency sweep* is unchecked then it is disabled.

The *Solvers* tab sets the parameters:

- *Solver*: selects the method for solving the linear system.
- *Max iterations*: maximum number of iterations allowed for the iterative solver.
- *Step iterations*: the value of the residual $||b - Ax||/||b||$ is shown every *Step iterations*.
- *Tolerance*: solution is reached when $||b - Ax||/||b|| <$ *Tolerance*.
- *Preconditioner*: selects a preconditioner for the iterative solver.
- *Initial guess*: reads a file with an initial guess for the iterative solver.
- *Results in file*: writes the solution of the linear system in a file.
  If *Results in file = No* then the option is disable.
  If *Results in file = Every step* then the solution is saved every *Step iterations*.
  If *Results in file = Final step* then the solution is saved when the solver finish.
- *External solver path*: if the option *External solver* is selected in *Solver* then ERMES writes the linear system in a file and executes *External solver path*.
- *Parameters*: parameters for the external solver.

The *Geometric Data* tab sets the parameters:

- *Dimensions*: If *Dimensions = 3D* then ERMES solves $\mathbf{E} = (E_x, E_y, E_z)$ in all the domain.
  If *Dimensions = 3D-Exy* then ERMES solves $\mathbf{E}$ with $E_z = 0$ in all the domain.
  If *Dimensions = 3D-Ez* then ERMES solves $\mathbf{E}$ with $E_x = E_y = 0$ in all the domain.
  If *Dimensions = 3D-Ea* then ERMES solves $\mathbf{E} = (E_\rho, E_\varphi, E_y)$ with $E_\rho = E_y = 0$ in all the domain (axis-symmetric problem around Y-axis).
- *Length factor (m)*: multiplies all the lengths for the factor indicated:
  If *Length factor (m) = m* then the factor is 1.
  If *Length factor (m) = dm* then the factor is 10.
  If *Length factor (m) = cm* then the factor is 100.
  If *Length factor (m) = mm* then the factor is 1000.
- *Normal type*: determines the type of smoothing for the boundary and contact normals.
- *Order*: order of the Lagrangian elements (1st, 2nd, 3rd or 4th).

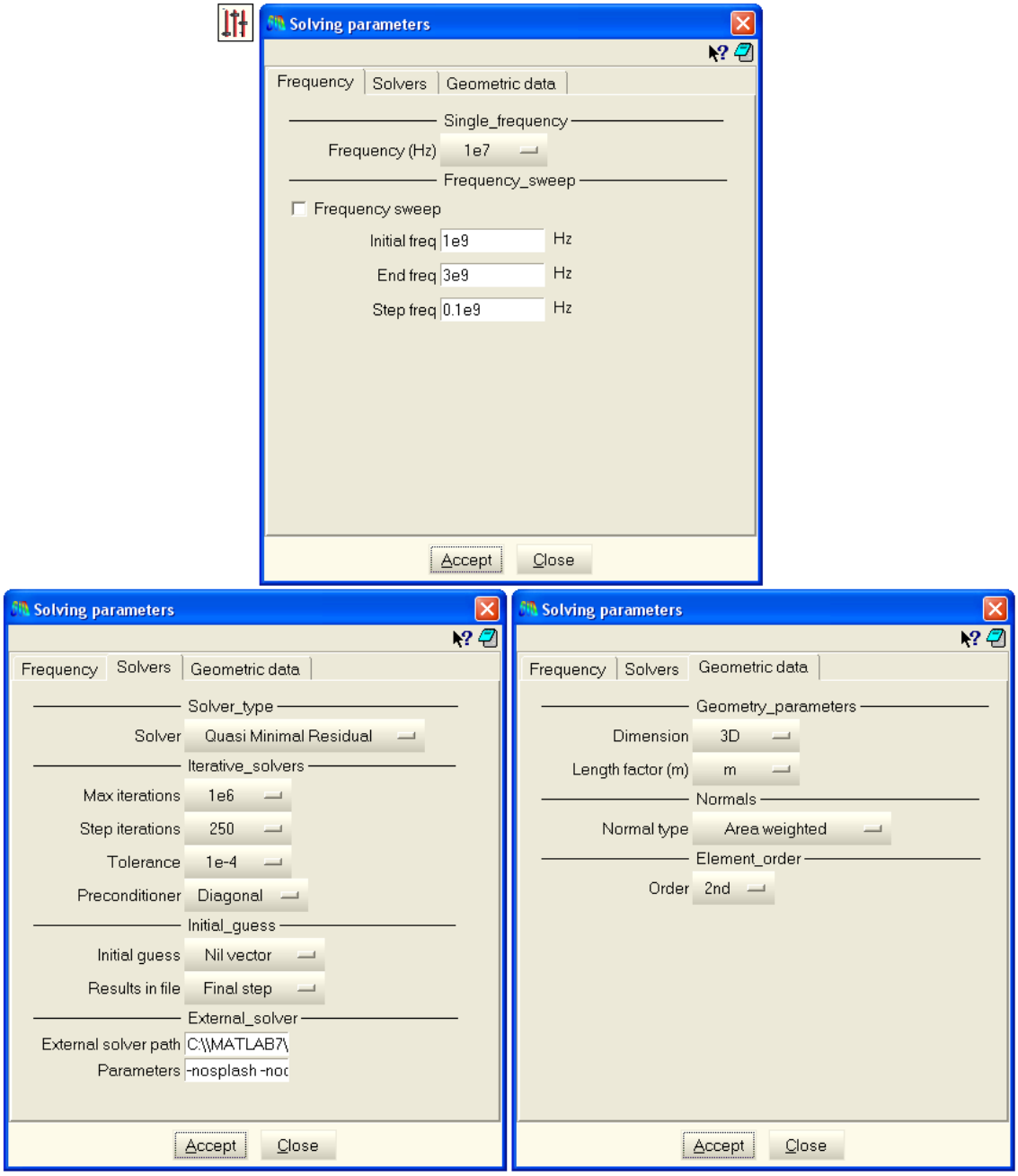

Figure 1.12: *Solving Parameters* window.

1.3.11 Results

The window *Results* (see fig. 1.13) selects the results to be displayed in the post process of GiD. It contains three tabs: *Frequency domain*, *Time domain* and *Geometric*.

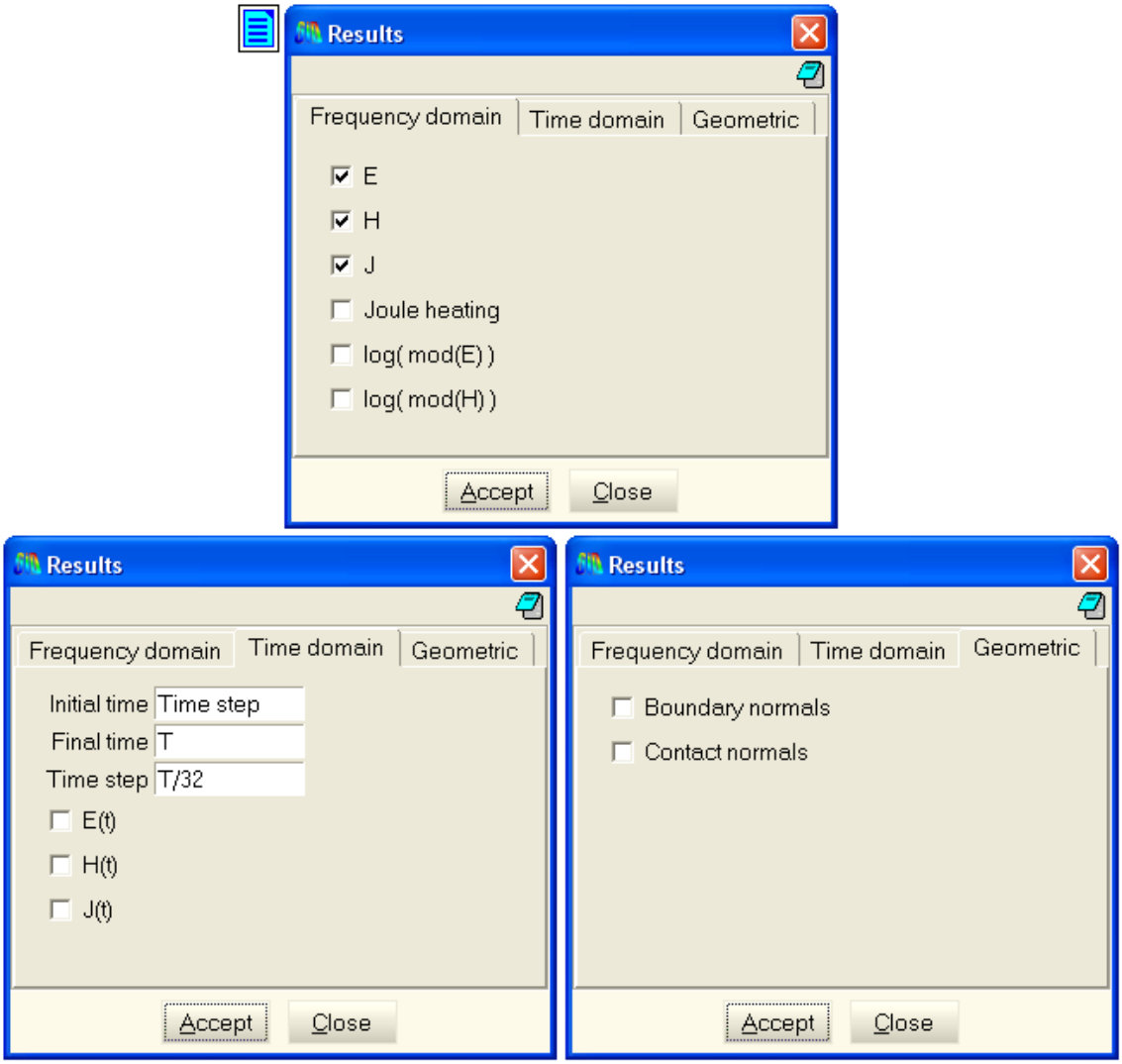

Figure 1.13: *Results* windows.

1.4 Post-Process

ERMES displays the results of the simulations in two different modes: *single frequency* and *frequency sweep*. In the following subsections we explain the characteristics of these modes.

1.4.1 Single frequency

If the checkbox *Frequency sweep* of the window *Solving Parameters* is unchecked then ERMES solves the problem for a single frequency and the results are stored in the file **.flavia.res*. This file located in the folder **.gid*. We can visualize the results by sending the **.flavia.res* file to the GiD post processor. The frequency domain results are in the time step 0 of the *View Results & Deformation* window that we can find in the upper menu of GiD *Window* → *View results*. The time domain results are in the time steps > 0 of the same window. The time domain results are obtained from the frequency domain results with the formula (see section 2.3):

$$\mathbf{F}(\mathbf{r},t) = Real\left[(\mathbf{F}_r(\mathbf{r}) + i\,\mathbf{F}_i(\mathbf{r}))e^{-i\omega t}\right] = \mathbf{F}_r(\mathbf{r})\cos(\omega t) + \mathbf{F}_i(\mathbf{r})\sin(\omega t). \tag{1.3}$$

In the file **.info*, also located in the **.gid* folder, we can retrieve information related to the solver (residual, size of the problem, iterations, time spent) and the values of the integrals over the surfaces (*intSurf*) and volumes (*intVol*) selected in the window *Modes Projection*.

1.4.2 Frequency sweep

If the checkbox *Frequency sweep* of the window *Solving Parameters* is checked then ERMES solves the problem for the frequencies in the interval (*Initial freq*, *End freq*) with a step of *Step freq*. The results for each frequency are stored in the files **.dat* located in the **.gid* folder. There is a file for every volume or surface selected in the *Modes Projection* window. The name of the surfaces files are *Surfn.dat*, where *n* is the ID of the surface. The name of the volume files are *Vn.dat*, where *n* is the ID of the volume. These files store the values of the surface integrals (*si*) and volume integrals (*vi*) of $\mathbf{E}$, $\mathbf{H}$, $\mathbf{J}$, $|\mathbf{E}|^2$, $|\mathbf{H}|^2$ and $|\mathbf{J}|^2$. If the surface is a waveguide port then the name is *S1j.dat*, being *j = 1* for the input port and *j = 2, 3, ...* for the output ports. In the files *S1j.dat* are stored the values of the scattering parameters S_{1j} for each frequency.

Bibliography

[1] GiD. The personal pre and post processor. *International Center for Numerical Methods in Engineering (CIMNE), Barcelona, Spain. [Online]. Available: http://www.gidhome.com*, 2010.

[2] R. Otin. Regularized Maxwell equations and nodal finite elements for electromagnetic field computations. *Electromagnetics*, 30:190–204, 2010.