EMF Visual

Electromagnetic exposure simulation software

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What is EMF Visual?

EMF Visual is a prediction, analysis and communication software tool which can accurately simulate the Electromagnetic field (EMF) exposure in both near and far field of the antennas while taking into account its environment.

This tool is based on ray tracing optical geometry computation models and provides very rapid assessment of the exposure around the radiating element using Graphical Processing Unit (GPU) accelerated computing.

EMF Visual is used by mobile phone operators, installers, municipalities, government agencies, regulatory and certification bodies, where a rapid and accurate evaluation of a given scenario is required.

The simulation tool is based on a five step process as presented in Fig.1 (a). First step is the definition of the complete 3D scenario. In this phase, the user can define or build a complete 3D scenario based on existing components provided with the software (buildings, ground profiles, etc.) There is a wide range of choice included in the software representing different types of buildings, roads, masts, towers, houses, and indoor objects. The user can select different electromagnetic properties for the materials.

Once the scenario is defined the second step is the antenna selection and installation inside the scenario. EMF Visual provides a wide database of generic antennas which can be used. In addition the BSA synthesis module can be used to add custom antennas to the scenario based on user defined specifications namely; frequency, beamwidth, tilt, input power, gain, etc. The user defined antennas can be exported to the EMF Visual database for use in different scenarios.

The third step is the definition of the computation volume inside the area of interest. Once the computation volume is identified, the calculation is launched taking into account the surrounding environment and the interaction with other radiating elements present in the scenario. As mentioned earlier the computation is based on ray tracing techniques. The user can select the mesh size of the computation volume and use a non-uniform grid in order to improve the resolution around the antennas and save computation time.

The E-field calculated at each point in the mesh is the superposition of the fields emitted by each sub-antenna of the radiating element (Fig.1 b). Once, the input power (P_{in}) and phase (α) of each sub-element is known, the total E-field can be calculated at any point '*p*' in the 3D space as the sum of the individual contributions [1], [2]. The results from a simple simulation with four radiating elements is presented in Fig.1 (b). The near-field distribution around the BTS antenna highlights the contribution of each sub-element as we move close to the antenna.

Once the simulation of the scenario is finished, the next step is to visualize the results. The user can define surface or cut-planes to visualize the E-field levels inside the scenario defined within the user defined computation volume. In addition to E-field, the software can display H-field, power density, percentage of power or percentage of field for multi-frequency sources. The software can also automatically determine the safe distance from the radiating element based on the standards / recommendations defined by the EU (*European Union*), ICNIRP (*International Commission on Non-Ionizing Radiation Protection*), or other regulatory and governing bodies. The user can also change the color and transparency of the results for optimal view.
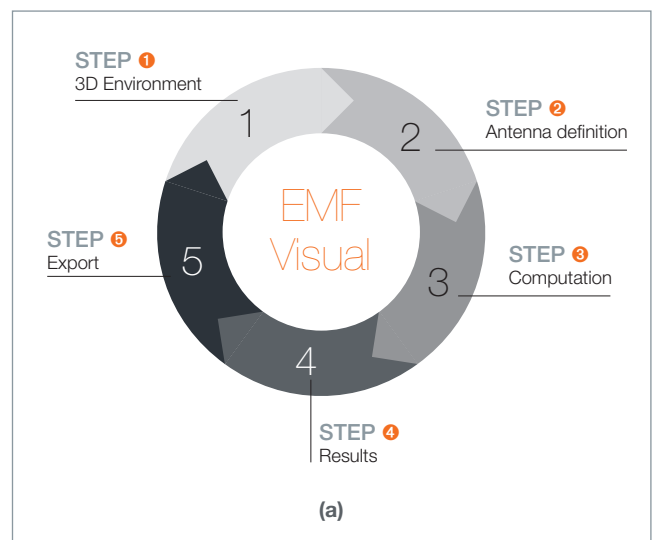
Design environment

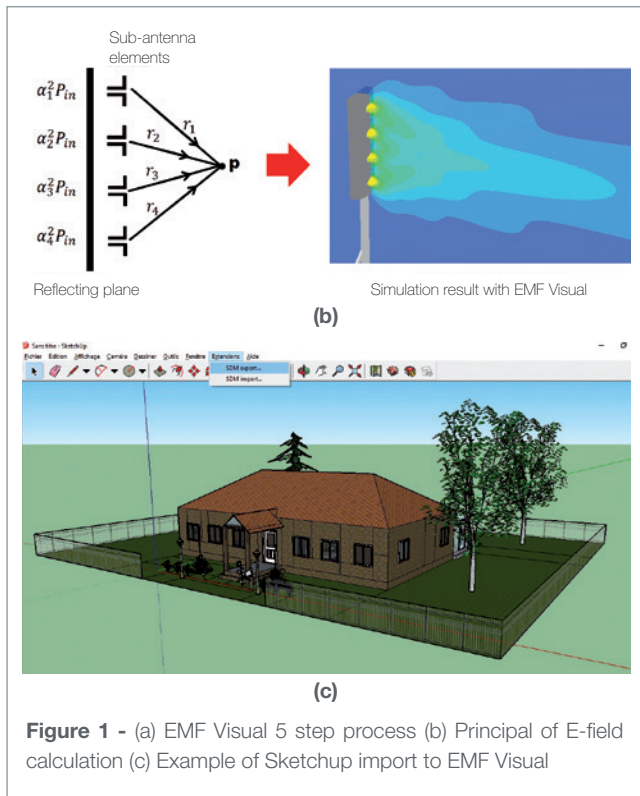**The scenario definition setup in EMF Visual provides several possibilities.**

The software package contains the standard EMF Visual tool with Central Processing Unit (CPU) or advanced GPU option. For a precise and rapid creation of 3D environment, several options are available. The user can use the internal generic database to build the 3D scenario. This database is quite comprehensive and provides a wide range of buildings, ground floors, towers, masts, indoor objects, etc.

The user can also opt for a plugin for "*SketchUP*" using the "*SE-SKP-EMF*" option [3], [4]. Using this module, the user can import custom structures into the EMF Visual software using the SDM format as shown in Fig.1 (c).

Another option is the terrain generation tool "*SE-AGETIM-Light-EMF*". The user can generate a complex 3D terrain using the Geographical Information System (GIS) user interface. The detail of the final output depends on the quality of input data.

The third option is the "*SE-FFT-EMF*" 3D conversion tool. It can be used to convert files from VRML, TDF, OpenInventor, and OpenFlight formats to the SDM format which is used by the EMF Visual. This tool is a package of several tools each used to convert to a specific file format.

(a)

Figure 1 - (a) EMF Visual 5 step process (b) Principal of E-field calculation (c) Example of Sketchup import to EMF Visual

Figure 2 - (a) Simulated far-field pattern from BSA Synthesis (b) Measured far-field pattern from SG64 system at MVG @ 2.14 GHz. The BTS antenna is shown.
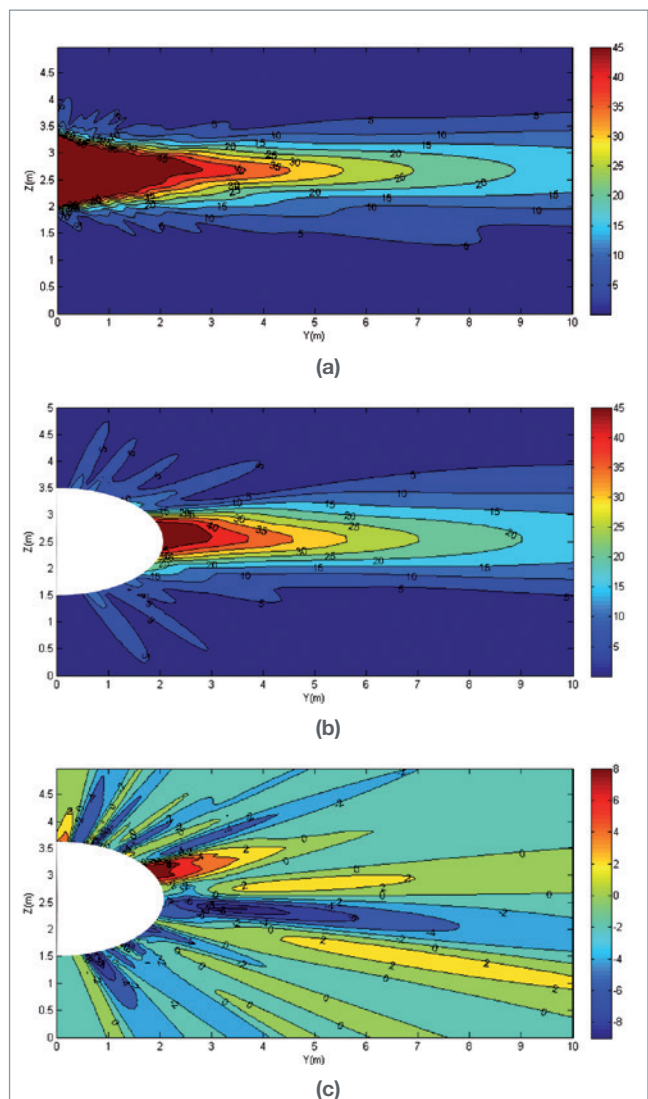
After the generation of the 3D environment using different methods discussed above, the next step before launching the calculation is the definition and placement of the radiating antenna element. A wide selection of base stations and antennas is included in the EMF Visual library. In addition, the user can create and define a custom antenna using the "BSA synthesis" tool which is included in the package (Fig. 1a, step#2). This tool provides a comprehensive yet friendly user interface which is used to evaluate the antenna performance in real time. The user can define several parameters such as gain, beamwidth, tilt, number of antenna elements and their individual amplitude and phase parameters, etc. The far-field radiation patterns of the custom antenna are shown instantaneously and the final custom antenna can then be exported to the EMF Visual library database for use in simulations.

▌Cast study: measurement of a BTS antenna

To investigate the results obtained from EMF Visual tool, a real base station (BTS) antenna was simulated and measured. The BTS antenna reference: *APXVLL13N-C* was provided by the RFS Company [5]. It was integrated in the EMF Visual software using the BSA Synthesis module. Then it was placed on top of a mast inside a simple scenario at a height of 2.5 m above the ground thus simulating a scenario free of environmental interference. The antenna simulation was carried out in the 2140 MHz band. The antenna gain at this frequency is around 17dBi with a vertical beamwidth of 7° and a 0° tilt was chosen. The input power was 43 dBm at the antenna input. The antenna horizontal beamwidth is 65°.
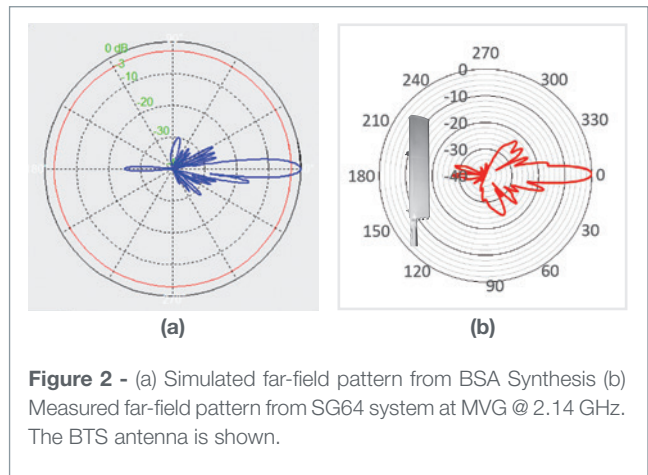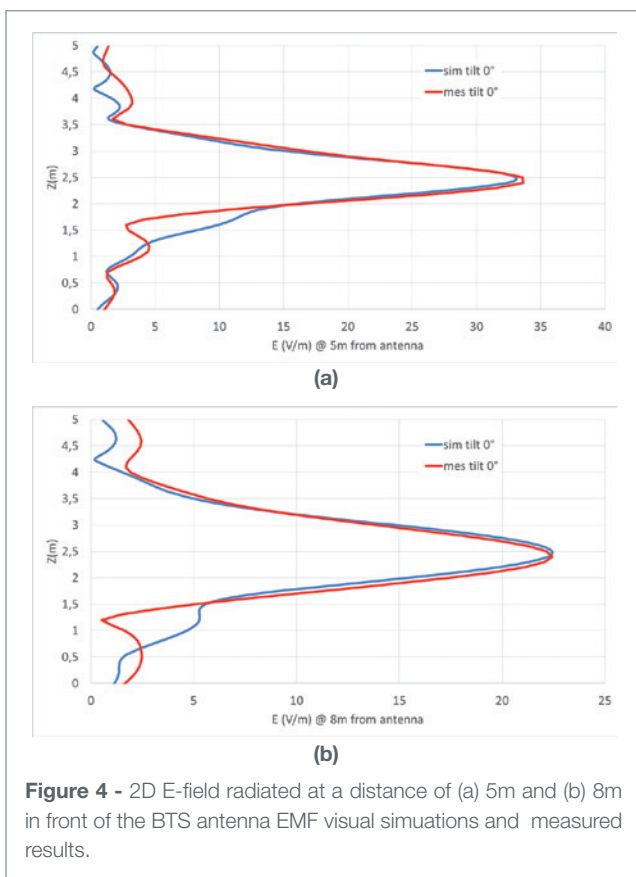
The same BTS antenna was measured inside the SG64 measurement chamber at MVG. The simulations and measurements were carried out at 2.14 GHz.

Figure 3 - 3D E-field radiated over a distance of 10m in front of the BTS antenna from (a) EMF Visual simuations, (b) Spherical mode expansion from measured near-field in SG64 system and post-processing by INSIGHT tool developed by MVG. (c) difference between simualtion and measurements in V/m.

The far-fields are compared in the Fig.2. We observe similar beamwidth, and side lobes between the simulations and measurements. There is a difference between lower side lobes and back lobes which is partially due to the fact that the simulations do not take into account the coupling between the different elements of the array and the measurements include the effects due to the support structure and connecting cables.

Secondly, the BTS antenna was simulated in EMF Visual and the E-field over a distance of 10m was evaluated inside a volume in front of the antenna. The results are shown in Fig.3 (a). The measured results from the near-field SG64 system were extrapolated using the near-field spherical modes data and the INSIGHT software developed by MVG. The E-field radiated by the antenna were thus estimated over the same 10m distance from the near-field spherical mode data.

(a)

(b)

Figure 4 - 2D E-field radiated at a distance of (a) 5m and (b) 8m in front of the BTS antenna EMF visual simuations and measured results.

The results are presented in Fig. 3(b). There is an exclusion radius of about 2m for the measured results including the sphere enclosing the antenna. Comparing the data obtained from EMF Visual simulation and spherical mode expansion from measurements Fig. 3(c), we can observe very good agreement. The results were normalized in order to represent same input power at the antenna input and thus to obtain similar E-field levels radiated from the BTS. The normalized error between simulations and measurements is less than 10% over most of the 10 m comparison range. For few angles the error increases up till 30%. These differences are partially attributed to the measurement setup and the coupling between the different elements which are not take in to account by the simulations.

The 2D cut-plane results are compared from simulations and measurements in Fig. 4 at 5m and 8m. Again we see very good agreement between the main beam obtained with small error in the side lobe levels due to the difference in the measurement and simulation setups as explained earlier.

▌Conclusions

The EMF Visual software provides a powerful and fast simulation solution for a complete exposure calculation with very accurate results. The new features provide the user with the possibility to import custom environment setups adapted to their requirements and in addition select different material properties to see the impact on exposure. In addition to a wide range of built-in generic antennas (from frequency modulation (FM) to high frequency LTE telecommunication bands), the user has the possibility to define custom antennas and use them in the simulation scenario after setting it to real site parameters. A case study scenario comparing simulation results to measurements provides very close agreement in the exposure levels and thus validate this powerful yet very fast simulation tool.

REFERENCES

[1] Y.Adane, A. Gati, M-Fa Wong, C. Dale, J. Wiart, and V. F. Hanna, "Optimal modeling of real radio base station antennas for human exposure assessment using spherical-mode decomposition.", IEEE Antennas and Wireless Propagation letters, Vol.1, 2002.

[2] Z. Altman, B. Begasse, C. Dale, A. Karwowski, J. Wiart, M.F. Wong, and L. Gattoufi, "Efficient models for Base Station Antennas for human exposure assessment.", IEEE Transactions on electromagnetic comptability, Vol. 44, no. 4, Nov. 2002.

[3] SketchUp software, available online: https://www.sketchup.com/.

[4] 3D objects libraray for use with SketchUp, available online at: https://3dwarehouse.sketchup.com/.

[5] RFS antenna company. More infromation online at: http://www.rfsworld.com/

For more information about EMF Visual, please visit our website:
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